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FLIGHT MEASUREMENTS OF THE EFFECTS OF A WING LEADING-EDGE SLOT AND OTHER MODIFICATIONS ON THE STABILITY, MAXIMUM LIFT, AND HIGH SPEED OF AN OBSERVATION AIRPLANE

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WASHINGTON

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MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

FLIGHT MEASUREMENTS OF THE EFFECTS OF A WING LEADING-EDGE SLOT AND OTHER MODIFICATIONS ON THE STABILITY, MAXIMUM LIFT, AND HIGH SPEED OF AN OBSERVATION AIRPLANE

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SUMMARY

Stability, maximum lift, and high-speed tests were made of an observation airplane fitted with Maxwell leading-edge slots.

Static and dynamic longitudinal and lateral stability was, in general, satisfactory and was little affected by the slots.

Maximum lift coefficients with power off were low due to early stalling at the center section. The Maxwell slots as installed reduced the maximum lift available by aggravating the center-section stall. Extending the slots all the way to the fuselage eliminated the detrimental effect, but the increase in lift over the slot-closed condition was small. Fully opening the cowl flaps eliminated a detrimental effect of opening the hoods in the landing condition. The stall warning, power off, was adequate, and with slots open was excellent. The highest lift coefficients were obtained with power on, but in this condition the stall warning was poor.

INTRODUCTION

Flight tests were made to determine the maximum lift and corresponding angles of attack, drag, and stability of an observation airplane equipped with Maxwell leading-edge wing slots. Various modifications were made to the airplane in an effort to increase the increment of maximum lift resulting from the Maxwell slots.

The lateral control characteristics of this airplane have been reported in reference 1.

DESCRIPTION OF AIRPLANE

The test airplane is a two-place, single-engine, mid-wing, cantilever monoplane with fixed landing gear, partial span deflector-plate flaps, combination aileron-spoiler lateral control, and Maxwell leading-edge slots extending from the wing tip to within approximately 14 inches of the fuselage (figs. 1 to 4). The dimensions of the airplane are:

Wing

Area, including section projected through fuselage	261.9 square feet
Span, b	35.89 feet
Taper ratio	1.5:1
Section, root	NACA 23015
Section, tip	NACA 23009
Incidence	3°
M.A.C. (fig. 5)	89.5 inches
Dihedral, outer panel chord line	7°

Ailerons

Type	Frise
Area aft of hinge line, each	6.7 square feet
Balance area, each	2.0 square feet
Span, each	31-percent semispan
Chord, average aft of hinge line	17.2-percent local wing chord
Droop	29° at full flap deflection

Spoilers

Type . . . . Ventilated and paddle balanced

Area, each . . . . 4.98 square feet

Span . . . . 41-percent semispan

Chord, average . . . . 10-percent local wing chord

Flaps

Type . . . . Slotted deflector-plate, spring-loaded to automatically decrease deflection at the higher loads

Area aft of hinge line, each . . . . 17.5 square feet

Span, each . . . . 51-percent semispan

Chord aft of hinge line, average . . . . 23-percent local wing chord

Slots

Type . . . . Maxwell

Span, each . . . . 69-percent semispan

Chord, average . . . . 15-percent local wing chord

Horizontal tail:

Span . . . . 17.17 feet

Total area . . . . 58.6 square feet

Elevator area aft of hinge line . . . . 24.0 square feet

Elevator balance area . . . . 1.83 square feet

Distance of elevator hinge line from wing leading edge . . . . 20.7 feet

Incidence . . . . 2°

Vertical tail

Span (height above fuselage)	5.25 feet
Total area	22.0 square feet
Rudder area aft of hinge line	11.5 square feet
Rudder balance area	1.18 square feet
Offset	2°, leading edge left
Distance of rudder hinge line from wing leading edge	19.0 feet

Engine

Type	R-985-50
Rating, take-off	450 bhp at 2300 rpm and 35.5 inches Hg. at sea level
Rating, normal	400 bhp at 2200 rpm at sea level and 5500 feet
Gear ratio	Direct drive
Carburetor	Automatic mixture control, type NA-R9C2
Fuel	92 octane
Maximum rpm limit	2860

Propeller

Type: Two-blade, constant-speed

Diameter	8.50 feet
Maximum blade angle range	15°
Index setting	24° at 42-in. station
High-pitch stop	22° at 42-in. station
Low-pitch stop	9° at 42-in. station

Plan and section views of the high-lift devices and control surfaces are shown in figures 6 to 10.

Modifications made to the airplane during the course of the tests were:

Modification 1.- Auxiliary slats were mounted ahead and above the normal leading edge of the wing root, overlapping the inboard end of the original Maxwell slot arrangement by about an inch (fig. 11).

Modification 2.- A fixed slot of the same contour as the Maxwell slot when open was constructed in the leading edge of the wing root between the fuselage and the inboard end of the original Maxwell slot (fig. 12).

Modification 3.- In addition to the slot extensions, the wing walkway was covered with fabric, filled, sandpapered smooth, and doped.

Modification 4.- In addition to the slot extensions, expanding wing-root fillets (fig. 13) were installed. The fillets started with approximately zero radius at the slot extension lip and expanded to a radius approximately equal to the width of the wing walkway at the trailing edge of the wing proper. From there the fillet was gradually faired back into the fuselage. The uncovered part of the wing walkway was in its original rough condition.

Modification 5.- The fillets were the same as in modification 4. The slot extensions, however, were replaced by the original wing-root leading edges.

Modification 6.- Air flow through the flap gap was prevented by sealing the lower surface with a strip of fabric.

APPARATUS

NACA instruments were used to record photographically as a function of time the following variables: airspeed, normal and longitudinal acceleration, rolling velocity, control position, stick force, flap position, change in altitude (statoscope), longitudinal inclination, and angle of sideslip.

Indicating instruments already in the airplane were used in observing pressure altitude, free air temperature, engine rpm, manifold pressure, and quantity of fuel carried.

For the drag tests only, where accurate comparisons of power were necessary, a total-pressure tube was placed in the slipstream (fig. 14) and connected to one side of an air-speed indicator in the cockpit. The other side of the meter was connected to the free-stream total pressure from the pitot head on the boom. The meter readings of this installation were then calibrated in terms of brake horsepower. The calibration was made on a single flight at a constant rpm and at several air speeds. The power was determined from observations of manifold pressure, rpm, altitude, temperature, and the calibration for the R-985-50 engine. By this method, the power determinations were made without recourse to the manifold-pressure gage and so were not influenced by unpredictable changes in power output for a given manifold pressure. Even though the power actually developed on the calibration flight may have been different from that shown on the standard engine calibration curves, the error was consistently carried through the subsequent test flights.

An airspeed head vaned and pivoted so as to aline itself with the relative wind in pitch, but not in yaw, was mounted on a boom near the left wing tip approximately one chord length ahead of the leading edge. The installation was calibrated in flight with a trailing bomb.

A yaw head was mounted on a boom near the right wing tip approximately one chord length ahead of the leading edge.

A two-element elevator and rudder control-position recorder was installed in the tail and attached directly to the control surface torque tubes. A two-element lateral stick-position and flap-position recorder was installed between the cockpits, the stick-position element being connected to the upper right side of the aileron-spoiler change-over unit, and the flap position recorder being connected to the right-hand section of the flap torque tube.

A two-element control-position recorder was also installed in each wing and connected directly to each aileron and spoiler.

Calibrations of the control surface deflections in terms of the cockpit control positions are shown in figures 15 to 27. As preliminary tests showed the most effective slot opening to be 1.5 percent of the local wing chord, no intermediate positions or linkage changes were used in the present tests, the slot gap for the slot-open tests being that shown for 30 turns in figure 27. In flight, it was found that the loads on the slot caused it to open the equivalent of approximately three crank turns more than when unloaded. For this reason, about 27 turns were used to fully open the slots in flight.

TESTS, RESULTS, AND DISCUSSION

Stability

The longitudinal and lateral stability was checked with the airplane in the original condition before any tests were made for maximum lift.

Characteristics of the uncontrolled longitudinal motion.- The characteristics of the uncontrolled short period longitudinal oscillation were measured with the center of gravity at approximately 26.3 percent mean aerodynamic chord and both hoods closed in the following flight conditions:

Power		Flap control setting	Slot	Cowl flaps	Approximate speed range, mph
bhp	rpm				
off		up	closed	closed	66 – 164
off		up	open	closed	54 – 110
off		full down	closed	closed	60 – 121
off		full down	open	closed	60 – 103
level		up	closed	closed	84 – 164
level		up	open	closed	79 – 103
level		full down	closed	open	87 – 121
level		full down	open	open	87 – 110
345	2300	up	closed	open	70 – 146
345	2300	up	open	open	60 – 103
345	2300	full down	closed	open	72 – 115
345	2300	full down	open	open	66 – 103

Where "level" power is referred to in this report it means power requred for level flight.

The results may be summarized as follows:

1. The variation of normal acceleration with time always damped out completely in less than one cycle.

2. In a few instances, the records of elevator angle showed oscillations of approximately 1-1/2 cycles, although the last half-cycle was of very small amplitude. These instances always occurred near the lowest trim speed with either flaps down, slots open, or both, and with little or no power being applied.

3. During runs with the flaps down, the flap position usually changed slightly; the change, however, was not of an oscillatory nature.

It is evident, therefore, that the requirements of reference 2 were met in most instances; the few control oscillations of more than one cycle had no apparent effect on the flying qualities.

Characteristics in steady straight flight.- The characteristics of the airplane in steady, straight flight with the center of gravity at approximately 26.3 percent mean aerodynamic chord and the hoods closed were measured in the following flight conditions:

Power		Flap control setting	Slot	Cowl flaps	Approximate speed range, mph
bhp	rpm				
off		up	closed	closed	74 - 149
off		up	open	closed	72 - 142
off		full down	closed	closed	61 - 105
off		full down	open	closed	62 - 104
level		up	closed	closed	66 - 160
level		up	open	closed	59 - 142
level		full down	closed	open	47 - 106
level		full down	open	open	44 - 104
345	2300	up	closed	open	63 - 158
345	2300	up	open	open	54 - 143
345	2300	full down	closed	open	46 - 104
345	2300	full down	open	open	45 - 107

The results are presented in figures 28, 29, and 30, and may be summarized as follows:

1. The variation of elevator angle with angle of attack was stable for all conditions of power with the flaps up, except with power on at the higher speeds with the slots open, where the curves indicate neutral stability. With flap down at low speeds, the airplane was stable in all conditions, but at the higher speeds instability appeared with power off, slots closed; with level-flight power, slots open; and with full power, slots open or closed. With power off, flaps up, a breakdown of the flow over the center section is indicated by the sudden increase in the slopes of the curves near stalling speed. With power off, flaps down, the flow breakdown caused pitching oscillations and the scatter of the data shown. With slots closed, there is less indication of flow breakdown. With power on, there is no indication of flow breakdown in any condition.

2. The variation of stick force with indicated airspeed shows control-free stability for all conditions except with power off, flaps up, slots open at the higher speeds. The center-section flow breakdown with power off at low speeds is again apparent in the sudden increase in the stick force required as the stall is approached.

3. The variation of rudder position with indicated airspeed with power on shows that approximately one-third right rudder was required to hold straight flight at minimum speed with the flaps up, and approximately two-thirds right rudder was required to hold straight flight at minimum speed with the flaps down.

4. The left sideslip at low speeds with power on was slightly greater than at high speeds. The indication of left sideslip with power off may have been due to position error in the yaw head.

5. When the flap control was in the full-down position, the flap started to float upward at an indicated air speed of about 75 miles per hour. With power on, full deflection was not available above approximately 60 miles per hour.

In general, it appears that the airplane was stable in the speed range in which it is likely to be used in each condition. With power off, the abrupt increase in elevator angle and stick force near the stall constituted an excellent stall warning. The early center-section stall, however, defeated to a certain extent the purpose of the high-lift devices incorporated in the wing. With the center-of-gravity position used in the stability tests, it was not possible to obtain a complete stall with the slots open and the stick full back in either the flaps-up or flaps-down condition with power off. This characteristic was apparently due to the deterioration of longitudinal control caused by the center-section flow breakdown with the resultant decrease in downwash angle and relative dynamic pressure at the tail. Heavy buffeting was present at minimum speed in this condition. With the slots closed, or with power on in any condition, no difficulty was encountered in obtaining a complete stall.

<u>Characteristics of the uncontrolled lateral motion.</u>- The characteristics of the uncontrolled lateral motion of the airplane when disturbed from steady flight were measured with the center of gravity at 26.3 percent mean aerodynamic chord and the hoods closed in the following flight conditions:

Power		Cowl flaps	Flap control setting	Slot	Approximate speed range, mph
bhp	rpm				
off		closed	up	closed	83 - 160
off		closed	up	open	88 - 162
off		closed	full down	closed	85 - 104
off		closed	full down	open	88 - 104
level		3/4 open	up	closed	71 - 157
level		3/4 open	up	open	93 - 147
level		3/4 open	full down	closed	64 - 105
level		3/4 open	full down	open	63 - 105
335	2200	open	up	closed	90 - 167
345	2200	open	up	open	71 - 168
330	2200	open	full down	closed	63 - 105
330	2200	open	full down	open	71 - 102

The tests were made by trimming the airplane at each test speed, abruptly applying rudder and aileron to produce a slip, releasing all controls, and recording the resultant motion of the airplane and controls.

The results are plotted in figures 31 to 34 and may be summarized as follows:

1. The period of the control-free lateral oscillation varied between 2 and 6 seconds and generally decreased with increasing airspeed.

2. The oscillation always damped to one-half amplitude in less than two cycles, thus meeting the requirement of reference 2. The damping was greatest at low speeds.

3. In no instance were the controls themselves observed to oscillate for more than one cycle, which also satisfies the requirements of reference 2.

The spiraling tendencies of the airplane were noted by the pilot during the previously mentioned tests of the control-free longitudinal motion. The spiral stability of an airplane has generally been considered to have little bearing on the flying or handling qualities of an airplane (reference 2). As a spirally stable airplane is, however, considerably easier to fly on instruments, the pilot's notes on this subject are summarized as follows:

1. Flaps up, slots closed. No immediate tendency to spiral in any power condition.

2. Flaps down, slots closed. No spiral power off; left or right spiral with power for level flight; pronounced tendency toward left spiral at 45 knots, right spiral at 85 knots, and spiral either way at intermediate speeds with full power on.

3. Flaps up, slots open. No spiral with power off or level flight power; left or right spiral at 50 knots, right spiral at 60 knots, eventual right spiral at 75 knots, no immediate spiral at 90 or 110 knots with full power on.

4. Flaps down, slots open. No immediate spiral power off; spiral either way up to 70 knots, no spiral at 85 knots with level flight power; left or right spiral at 50 or 60 knots, no spiral at 70 or 85 knots with full power on.

Characteristics in steady sideslipping flight.- The characteristics of the airplane in steady sideslipping flight were measured in the following conditions with the center of gravity at 26.3 percent of the mean aerodynamic chord:

Power		Cowl flaps	Flap control setting	Slot	Hoods	Indicated speed tested, mph approximate
bhp	rpm					
off		closed	up	closed	closed	86, 120, 166
off		closed	up	open	closed	86, 102, 133
off		closed	1/3	closed	closed	79, 98, 126
off		closed	1/3	open	closed	75, 98, 126
off		closed	full down	closed	closed	75, 85, 102
off		closed	full down	open	closed	74, 85, 102
off		closed	full down	open	open	76, 85, 101
340	2300	open	up	closed	closed	74, 123, 166
340	2300	open	up	open	closed	68, 105, 135
340	2300	open	1/3	closed	closed	73, 100, 126
340	2300	open	1/3	open	closed	63, 98, 126
340	2300	open	full down	closed	closed	66, 85, 101
340	2300	open	full down	open	closed	60, 86, 103
340	2300	open	full down	open	open	60, 84, 101

The results of the measurements are shown in figures 35 to 48 and may be summarized as follows:

1. In general, the variation of cross-wind force with angle of sideslip was such that increasing right bank accompanied increasing right sideslip, and vice versa, as required in reference 2. (In steady sideslips, the cross-wind force on an airplane varies directly as the angle of bank (reference 2). A large variation of angle of bank with angle of sideslip enables a pilot to judge his angle of sideslip easily.) In certain conditions at low speed, however, the variation of bank with slip was neutral at small angles of slip or slightly negative in right sideslips (figs. 37, 39, 40, 42, 43, 44, 45). Opening the slot or deflecting the flap had no pronounced or consistent effect. As usual, the cross-wind force with power on exceeded that with power off.

2. The rolling moment due to sideslip with stick fixed (as indicated by the variation of lateral stick position with angle of sideslip) tended to restore the airplane to its original attitude for all conditions except with flap full down, power on, in right sideslips, especially at low speed. The variation with slot position, flap position, power, and speed was small except for the case noted above.

The rolling moment due to sideslip with stick free (as indicated by the variation of lateral stick force with angle of sideslip) varied considerably with the several airplane conformations. In all the lowest speed conditions the stick-free lateral stability was low, and in right sideslips a force reversal sometimes occurred, especially with flaps down, power on. In general, the stick-free stability was lowest with the flaps one-third down. With flaps full down, the stick-force variation was large for small angles of slip, but small for large angles.

3. The variation of yawing moment due to sideslip, as given by the variation of rudder angle with angle of sideslip, was considered adequate in all conditions, in that the rudder angle was approximately proportional to the sideslip angle and no decrease in the slope of the curves at small angles of yaw was observed. The slope increased progressively with flap deflection, but changes with slot position or power were negligible, except with flaps full down, where a small increase in slope resulted on application of power. At large angles of right sideslip, especially with power on, a rudder-force reversal noted by the pilots indicated tail stalling and rudder-free instability.

4. The pitching moment due to sideslip (as indicated by the variation of elevator angle and elevator stick force with angle of sideslip) was generally small. Only at the lowest speeds with flap up, power on, slots closed or open, and with flaps one-third down, power on, slots open, did the elevator angle for balance move more than the maximum allowance as given in reference 2, 1° for 5° rudder movement from trim.

5. Figures 49 to 51 give an indication of the stretch in the control system that occurred in the sideslips and enables actual control surface position to be determined for the stick positions shown in figures 35 to 48. The control positions shown were measured by the control position recorders in the wings.

Maximum Lift

Extensive measurements were made of the maximum lift of the airplane in various conformations and with several modifications. The data are presented in tables I to VII. Blank spaces left in the tables indicate that data were not obtained, or that the particular configuration was not tested.

In order to make it possible to stall the airplane in all conditions, the center of gravity was moved back to approximately 32.5 percent of the mean aerodynamic chord. No measurements of stability were made in this condition, but the pilots had no difficulty in flying the airplane.

The maximum lift coefficient was calculated from the data by means of the following formula:

$$C_L = \frac{W \cos\theta \, A_R}{qS} \tag{1}$$

where

W weight, pounds

θ flight-path angle

A_R resultant acceleration, g's

q dynamic pressure, pounds per square foot

S wing area, square feet

In determining the weight, allowance was made for the fuel used. The flight-path angle was determined from the vertical velocity (measured with a statoscope) and the velocity along the flight path (true speed determined from records of indicated airspeed and notes of pressure altitude and free air temperature).

If it had been possible to take all records in perfectly steady flight, the A_R term (resultant acceleration in g's) could have been omitted from formula (1). In this airplane, however, the early center-section stall usually made it difficult for the pilot to hold absolutely steady flight at minimum speed. Introduction of the A_R term in the formula involves the assumption that the resultant acceleration is vertical; omitting the term altogether resulted in considerably more scatter of the data and a tendency toward optimistic values of the maximum lift.

The angle of attack was determined from the flight-path angle and the inclination of the airplane as determined by a recording inclinometer. The angles of attack shown in the tables are referred to the wing chord line. When necessary, the readings of the inclinometer were corrected for horizontal acceleration. Because of the buffeting and uncertain point of stall, the angles of attack shown should be considered only approximate; they may be relied upon, however, to show the trend from one condition to another.

Assuming a landing of zero vertical velocity and one g vertical acceleration, stalling speeds for landings were computed from the maximum lift coefficients by the following formula:

$$V_{L_{mph}} = \sqrt{W/0.0025\ C_{L_{max}}} \tag{2}$$

The weight was taken as 4800 pounds.

Elevator angles at the stall, as with the angles of attack, should be taken as only approximate.

Observations of the stalling characteristics were made by an observer in the rear seat with the aid of tufts on the inboard half of the wing.

The results of the maximum lift measurements are discussed for each modification.

Maximum lift in the original condition.- As shown by table I, the maximum lift coefficients obtained with power off were low and opening the slot had a detrimental effect. Opening the hoods or cowl flaps had varying effects, depending on the flap and slot position. In the landing condition (flaps down, hoods open), the highest lift coefficient was obtained with the cowl flaps open.

The decreased maximum lift coefficient with the slots open was probably due to a change in span load distribution which tended to load up the unslotted center section more with slots open than with slots closed for a given over-all lift coefficient. Once the center section stalled completely, little or no benefit was gained by increasing the angle of attack further. It appeared that the expected added lift on the outboard sections of the wing was offset by the outward spread of the stall.

The power-off stall warning with the slots closed was considered adequate, as moderate buffeting preceded the roll-off. The power-off stall warning with the slots open was excellent as heavy buffeting set in and a rolling and pitching oscillation developed, with no uncontrollable roll-off.

Tests were made with various amounts of power, slots open and closed, with flaps down and hoods and cowl flaps open. The results are shown in figure 32. It is seen that even a small amount of power (approx. 100 bhp) increased the maximum lift coefficient by about 0.5. Tests with approximately 300 brake horsepower at 2200 rpm for several configurations (table I) showed an increase in maximum lift coefficient of 0.96 to 1.30 over the power-off value. These increases appear to have been due to both the direct forces on the propeller and the elimination of the center-section stall.

According to reference 3, the lift due to power is a direct function of the thrust, and where there is no premature stalling at the center section, the added lift should be numerically equal to the thrust. The maximum lift coefficient can therefore be expressed as follows:

$$C_{L_{max}} = C_{L_1} + C_{L_2} + kT_c$$

where

C_{L_1} maximum power-off lift coefficient

C_{L_2} increment of lift coefficient due to elimination of center-section stall

k a constant (unity, according to reference 3)

T_c thrust coefficient based on dynamic pressure and wing area (T/qS)

Using the data shown in figure 52, the value of k for this airplane was found to be 1.0, thus showing agreement with the conclusions of reference 3.

With the power on, the wing always stalled near the tip, the airplane rolling left or right depending on the slot position. No warning was apparent in the form of buffeting, but the attitude angle was high (20° to 25°). Although the airplane was descending at the time of stall even at the higher powers, it was found impossible to make landings with high power as a positive rate of climb resulted when near the ground.

The measured increment of maximum lift coefficient due to opening the slots at any power is also shown in figure 52. The constant increment of 0.14 shown at all powers above approximately 80 brake horsepower could be expected to apply with power off as well, if the center-section stall were eliminated. The reduction in stalling speed corresponding to this increase in maximum lift is only 1 or 2 miles per hour. On this basis, the added weight and complication of the Maxwell slot installation could hardly be justified even in an arrangement free of early stalling at the center section.

Maximum lift with modification 1 (auxiliary slats).--As shown in table II, the addition of the auxiliary slats delayed the center-section breakdown sufficiently to cause increases of up to 0.37 in the maximum lift coefficient. The detremental effect of opening the slots was also eliminated, although no consistent increase in lift coefficient due to opening the slots was measured. As in the original condition, in the landing conformation (flaps down, hoods open), the lowest stalling speed was attained with the cowl flaps open.

Maximum lift with modification 2 (Maxwell slot extensions).-Extending the Maxwell slots to the fuselage offered a small increase in maximum lift with the slot-open over the slot-closed condition (table III). The lowest stalling speed with the hoods open was obtained when the cowl flaps were open. The Maxwell slot extensions were slightly less effective than the auxiliary slats in reducing the stalling speed.

Maximum lift with modification 3 (Maxwell slot extensions with smooth walkway).-Smoothing the wing walkways in an attempt to delay the separation at the center section resulted in neither an improvement nor a detrimental effect (table IV).

Maximum lift with modification 4 (Maxwell slot extensions with wing-root fillets).-The combination of Maxwell slot extensions and wing-root fillets produced the best improvement in power-off maximum lift (table V). In the landing condition, the highest lift coefficient (1.97) was again obtained with the cowl flaps open. Tests made with partial cowl-flap openings in the landing condition (hoods open, flaps down) showed that it was necessary to have them at least three-quarters open to secure a beneficial effect.

Tests with the flap up and the slots open showed increases in $C_{L_{max}}$ of up to 0.66 over that obtained in the original condition.

As would be expected, the power-on lift coefficients were about the same as in the original condition.

Maximum lift with modification 5 (wing-root fillets only).-With the wing-root fillets only, the greatest increases in maximum lift coefficient were 0.53 with flaps up, slots open, and 0.17 with the flaps down, slots closed (table VI). As in the original condition, the stalling speed with flaps down was lower when the slots were closed than when they were open. As usual, when the hoods were open in the landing condition, the highest lift coefficient was obtained with the cowl flaps open.

Maximum lift with modification 6 (wing flap gap sealed on lower side).- In the flaps-down, slot-closed, power-off condition with the flap gap sealed on the lower surface, the maximum lift coefficient was decreased by 0.02 to 0.24, depending on the hood and cowl-flap positions (table VII). After a few degrees of flap movement from the full-up position, the tufts on the upper surface changed direction so that they pointed straight in toward the fuselage. This change did not occur with the gap unsealed, even in the full-down position. The glide path was steeper with the flap gap sealed.

General discussion.- The low maximum lift of the test airplane appears to have been due to an early center-section stall. This condition was aggravated by opening the slots when they did not extend all the way to the fuselage.

The variation of maximum lift coefficient with the position of the hoods and cowl flaps was often large. With flaps down, cowl flaps closed, opening the hoods usually resulted in a marked decrease in the maximum lift available, both in the original condition and with the various modifications. In some instances the decrease in $C_{L_{max}}$ was as much as 0.31. Opening the cowl flaps in addition, however, would always improve and often eliminate entirely the adverse effect of the open hoods. This effect may have been due either to added turbulence in the air stream delaying the separation from the wing root, or to a favorable change in pressure distribution over the fuselage and wing-root juncture.

Of the several modifications tried in an attempt to improve the maximum lift of the airplane, all succeeded to a greater or lesser extent. The combination of slot extensions and wing-root fillets produced the greatest improvement. The maximum power-off lift coefficient measured in this condition was 2.01 as compared with 1.88 in the original condition. It is doubtful that any simple modification would reduce the stalling speed much below that measured in this condition, as in some conformations the stall was starting farther out on the wing, showing that the center-section stall (the primary cause of the low maximum lifts) was suppressed.

With power off, the Maxwell leading-edge slot was found to be effective only when extended all the way to the fuselage. The use of a Maxwell slot that did not extend all the way to the fuselage resulted only in aggravating an inherently early center-section stall. With the flaps down, this is also true whether the airplane is equipped with fillets or not, although with flaps up the fillets alone did effect some improvement. Had the airplane been one that normally stalled first at the wing tips, it is possible that the slots would have proved helpful as installed.

As the maximum lift was raised by progressive elimination of the center-section stall, the stall warning in the form of buffeting was decreased.

Except when the flap gap was sealed, the stall was always observed to start on the wing proper; tufts on the upper surface of the slotted deflector-plate flap were never observed to fluctuate or reverse.

The simplest way of increasing the maximum lift was by the application of power; even a small amount of power delayed the stall at the center section and effected a greater increase in $C_{L_{max}}$ than any of the modifications tested. The main objection to the use of power was the fact that it eliminated the stall warning, and power would not be available in case of engine failure.

With power on, the airplane would roll left at the stall with the slots closed, and right with the slots open. A general tendency toward high angles of right sideslip and large loss of altitude was also noted in the slot-open, power-on stalls. A time history of a rather severe instance of this is shown in figure 53. It appears that the airplane started to recover from the resulting dive at the time the flap started retracting due to the increased speed.

Landing recommendations.- Consideration of the data leads to certain recommendations for landing the test airplane with Maxwell leading-edge slots.

For minimum power-off landing speed, the cowl flaps should be kept fully open. This practice eliminated adverse effects of the open hoods. The slots should be closed with the unmodified airplane. The stall warning appeared adequate and the maximum lift was higher in this condition.

It is possible that opening the original slots, which keeps the outer wing sections unstalled to relatively high angles of attack (but not high total wing lift), may give improved lateral control in rough-water landings with the seaplane model when the aircraft is bounced to an angle of attack sufficiently high to completely stall the unslotted wing. The power-off stall warning was very pronounced in this condition.

For absolute minimum landing speed, all the power possible without climbing should be applied. The stall warning in this condition is negligible.

The maximum angles of attack with power on, or with slots open, power off, when the center-section stall was suppressed were from 20° to 25°. The normal three-point landing attitude of conventional airplanes is 10° to 15°. The pilots found that practice and care were necessary to perform landings at the attitude corresponding to maximum lift. Evidently other factors in the landing maneuver had predominant effects, as no consistent difference in speed between three-point and tail-first landings was noticed in the limited number of landing records taken. A time history of a power-off, three-point landing with the slot extensions and smooth walkway, flaps down, slots, hoods, and cowl flaps open, is shown in figure 54. The recorded airspeed at contact was 60 miles per hour, or 1.5 miles per hour lower than the stalling speed for that condition as given in table IV. This difference may possibly be accounted for by the error in airspeed reading caused by the increased static pressure around the airplane when it is close to the ground. Statoscope readings made on the ground in take-offs showed this error to amount to about 3 miles per hour for this airplane.

Maximum Speed and Drag

Except as noted, all maximum speed results reported in this section are for 400 brake horsepower, 5500 feet density altitude, and 4800 pounds weight.

Preliminary flights indicated that the slot doors would blow up slightly in high-speed flight, the resulting drag increase causing a reduction in maximum speed. In the present tests it was noted that vibration in flight would cause the slot-actuating crank to rotate approximately one-half turn from the fully-closed position. A hook was then arranged to hold the crank in the fully-closed position. A check of the high speed made with the slots thus closed, and locked closed by means of screws through the doors themselves, showed no difference in high speed.

It was found that installation of the auxiliary slats reduced the top speed of the airplane 7 miles per hour.

To determine the increase in performance, if any, which would result from preventing air flow through the flap gap, identical flights were made by each of three different pilots for sealed and unsealed flap conditions. Differences in piloting technique caused considerable scatter of the data, but the general trend seemed to indicate only about a 2-mile-per-hour increase in level-flight high speed when the flap gap was sealed. The maximum speed recorded in these tests in the normal condition was 176 miles per hour (fig. 55). As sealing the flap also increased the landing speed somewhat, the effective speed range was not appreciably altered.

A measure of the drag of the unmodified airplane was obtained by determining the power required for level flight in the following conditions:

1. Flaps up, slots closed, hoods closed

2. Flaps up, slots open, hoods closed

3. Flaps set for 16.5° deflection, slots closed, hoods closed

4. Flaps set for 16.7° deflection, slots open, hoods closed

The results are shown in figures 55 to 58. The large increase in power required shown when the cowl flaps were opened may be excessive, as the total-head meter was seen to increase reading as the cowl flaps were opened. The meter was calibrated with the cowl flaps closed. The comparative results for the different wing, flap, and slot conformations are, however, believed valid.

The partial flap deflection is seen to have reduced the power required by about 7 percent at low speeds, but the open slots appear to have increased the power required by varying amounts at any speed except perhaps at the very lowest speeds with the flaps deflected.

CONCLUDING REMARKS

The results of the tests reported herein are summarized as follows:

1. At the center-of-gravity positions tested, the static and dynamic longitudinal and lateral stability was, in general, satisfactory. The slots had only minor effects on the stability characteristics.

2. The low maximum lift coefficient of the test airplane was due to an early center-section stall. Opening the Maxwell slots as originally installed only aggravated this condition, resulting in still lower maximum lift.

3. Opening the hoods in the landing condition (power-off, flaps-down) usually reduced the maximum lift coefficient considerably. Opening the cowl flaps in addition practically eliminated the adverse effect of the open hoods.

4. Extending the slots all the way to the fuselage eliminated their detrimental effect on the maximum lift, but the decrease in landing speed over the slots-closed condition was only 1 or 2 miles per hour.

5. Wing-root fillets alone increased the maximum lift to a practical degree only in the flap-up condition. When combined with the slot extensions, the fillets also caused small increases in maximum lift in the flaps-down condition.

6. With the slots open in the original condition, the power-off stall warning in the form of buffeting and increased stick travel and force near minimum speed was excellent. The power-off stall warning is believed to have been adequate in the slot-closed and the improved slot-open conditions.

7. The highest lift coefficients were obtained with power on; even a small amount of power had as much or more effect than any of the modifications tried. With the center-section stall eliminated, the stall warning was poor.

8. With power on, and with power off when the slots were open and the center-section stall was suppressed, the stalling attitude was 20° to 25°, compared to 10° to 15° for the normal three-point landing attitude. In a limited number of actual landings, no consistent reduction in landing speed was obtained by going beyond the three-point attitude.

9. The slots as originally installed might be useful in the seaplane version of the airplane during rough-water landings by keeping the outer wing sections unstalled and retaining some measure

of lateral control when the airplane is bounced to an angle of attack high enough to stall the whole unslotted wing. With the slots extended to the fuselage, the same feature would be present with the added advantage of lower available power-off landing speeds.

10. Reducing the drag of this airplane by sealing the flat gap did not increase the speed range, as the landing speed was increased as well as the high speed.

11. Partial flap deflection reduced the power required for level flight at low speeds, but opening the slots increased the drag in all conditions except at the very lowest speeds with flaps deflected.

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REFERENCES

1. Clousing, Lawrence A., and McAvoy, William H.: Flight Measurements of the Lateral-Control Characteristics of an Airplane Equipped with a Combination Aileron-Spoiler Control System. NACA CMR, Sept. 1942.

2. Gilruth, R. R.: Requirements for Satisfactory Flying Qualities of Airplanes. NACA ACR, April 1941.

3. Diehl, Walter S.: Some Fundamental Considerations in Regard to the Use of Power in Landing an Airplane. NACA TN No. 692, 1939.

TABLE I. ORIGINAL CONDITION

POWER	FLAPS	SLOTS	HOODS	COWL FLAPS	NO. OF RUNS AVERAGED C_L	NO. OF RUNS AVERAGED α	C_L MAX.	V_L AT 4800 LBS., MPH	α WING CHORD MAX., DEG.	C.G. POSN. % M.A.C. BEFORE TAKE-OFF	APPROX. ELEV. ANGLE TO STALL, DEG. +=DN	FIRST PARTS OF WING TO STALL	BUFFETING	MOTION AT STALL AND ADDITIONAL COMMENTS
OFF	UP	C	C	C	3	3	1.16	78.5	15	32.1	- 4	L.CENTER SECTION	LT.-MED.	L.ROLL
			C	O	4	4	1.25	75.5	17		- 5	L.CENTER SECTION	MED.	L.ROLL
			O	C	3	3	1.26	75.5	18		-10	BOTH CENTER SECTIONS	MED.	R.ROLL
			O	O	4	4	1.36	72.5	19		- 6	R. WING	MED.	ABRUPT R.ROLL
		O	C	C	4	4	1.10	80.5	15	32.3	- 5	BOTH CENTER SECTIONS	MED.-HEAVY	NO ROLL
			C	O	3	3	1.07	82.0	14		- 6	L.CENTER SECTION	MED.-HEAVY	NO ROLL
			O	C	4	4	1.06	82.0	13		- 5	L.CENTER SECTION	MED.-HEAVY	NO ROLL
			O	O	3	3	1.17	78.5	17		- 8	R.WING	MED.-HEAVY	ROLL.OSCILLATION
	DN	C	C	C	6	6	1.88	62.0	16		- 5	CENTER SECTIONS	MED.	ROLL.OSCILLATION
			C	O	7	7	1.85	62.0	16		- 6	CENTER SECTIONS	MED.-HEAVY	ROLL.OSCILLATION
			O	C	7	7	1.71	65.0	17		-18	L.CENTER SECTION	MED.	ABRUPT L.ROLL
			O	O	7	7	1.84	62.5	17		- 8	BOTH CENTER SECTIONS	MED.	PITCH-DN OR L.ROLL
		O	C	C	7	7	1.71	65.0	15		-11	BOTH CENTER SECTIONS	MED.-HEAVY	ROLL.OSCILLATION THEN PITCH-DN
			C	O	7	7	1.62	66.5	12		- 6	L.CENTER SECTION	MED.	ROLL. & PITCH.OSCILLATION
			O	C	7	7	1.64	66.0	13		-11	L. CENTER SECTION	MED.	ROLL.OSCILLATION & MILD PITCH-DN.
			O	O	7	4	1.77	63.5	13		- 7	L. CENTER SECTION	MED.-HEAVY	ROLL.OSCILLATION & MILD PITCH-DN.
300BHP	UP	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										
	DN	C	C	C	4	4	2.84	50.0	23	32.1	+ 2	OUTBOARD WING	NONE	L.ROLL
			C	O	4	4	2.81	50.5	22		+ 3	OUTBOARD WING	NONE	L.ROLL
			O	C	4	4	2.72	51.5	22		+ 2	OUTBOARD WING	NONE	L.ROLL
			O	O	4	4	2.81	50.5	22		+ 3	OUTBOARD WING	NONE	L.ROLL
		O	C	C	4	4	2.85	50.0	29		- 2	OUTBOARD WING	NONE	R.ROLL
			C	O	4	4	2.90	49.5	28		0	OUTBOARD WING	NONE	R.ROLL
			O	C	4	3	2.94	49.5	29		0	OUTBOARD WING	NONE	R.ROLL
			O	O	4	3	2.88	50.0	27		+ 3	OUTBOARD WING	NONE	~~R.ROLL~~
88BHP		C	O	O	4	4	2.26	56.5	18		- 2	L.OUTBOARD WING	NONE	L.ROLL
265					4	4	2.67	51.5	19		+ 2	L.OUTBOARD WING	NONE	L.ROLL
392					5	5	2.92	49.5	22		+ 5	L.OUTBOARD WING	NONE	L.ROLL
85		O	O	O	4	4	2.40	54.5	24		- 7	L.WING,THEN R.	NONE OR LT.	R.ROLL & FAIRLY STEEP DIVE
260					4	4	2.78	50.5	26		+ 1	L.REAR OUTBOARD WING	NONE	R.ROLL & STEEP DIVE
364					5	5	3.07	48.0	27		+ 2	L.REAR OUTBOARD WING	NONE	R.ROLL & PITCH-DN OR NO ROLL & L.TURN. FULL R.RUDDER NECESSARY FOR STRAIGHT FLT. AT MIN. SPEED.

TABLE II. MODIFICATION 1. AUXILIARY SLAT

POWER	FLAPS	SLOTS	HOODS	COWL FLAPS	NO. OF RUNS AVERAGED C_L	NO. OF RUNS AVERAGED α	C_L MAX.	V_L AT 4800 LBS., MPH	α WING CHORD MAX., DEG.	C.G. POSN. % M.A.C. BEFORE TAKE-OFF	APPROX. ELEV. ANGLE TO STALL, DEG. +=DN	FIRST PARTS OF WING TO STALL	BUFFETING	MOTION AT STALL AND ADDITIONAL COMMENTS
OFF	UP	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										
	DN	C	C	C	4	4	1.98	60.0	16	32.1	- 5	OBSERVATIONS INCOMPLETE		NO ABRUPT ROLL
			C	O	4	4	2.01	59.5	16		- 4			L.ROLL
			O	C	4	4	1.70	65.0	18		-17			R.ROLL
			O	O	4	4	1.88	62.0	18		- 8			ABRUPT R.ROLL
		O	C	C	4	4	1.99	60.0	23		-13			R.OR L.ROLL
			C	O	4	4	1.99	60.0	21		- 7			R.ROLL
			O	C	3	3	1.77	63.5	23		-29		HEAVY	STALL INCOMPLETE. VALUES ARE FOR MIN. SPEED WITH STICK FULL BACK.
			O	O	4	4	1.86	62.0	24		-25			ABRUPT R.ROLL. ROLL-OFF USUALLY AS NOTED, BUT SOMETIMES WOULD NOT ROLL-OFF WITH STICK FULL BACK.
300BHP	UP	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										
	DN	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										

TABLE III. MODIFICATION 2. MAXWELL SLOT EXTENSION

POWER	FLAPS	SLOTS	HOODS	COWL FLAPS	NO. OF RUNS AVERAGED C_L	NO. OF RUNS AVERAGED α	C_L MAX.	V_L AT 4800 LBS., MPH	α WING CHORD MAX., DEG.	C.G. POSN. % M.A.C. BEFORE TAKE-OFF	APPROX. ELEV. ANGLE TO STALL, DEG. +=DN	FIRST PARTS OF WING TO STALL	BUFFETING	MOTION AT STALL AND ADDITIONAL COMMENTS
OFF	UP	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										
	DN	C	C	C	7	5	1.85	62.5	15	32.1	- 6	L. WING		L.ROLL
			C	O	8	4	1.88	62.0	16		- 7	BOTH WING & CENT.SECT.		L.ROLL USUALLY
			O	C	8	4	1.71	65.0	20		-22	CENT.SECT. SLIGHTLY STALL		SHARP R.ROLL
			O	O	8	4	1.85	62.5	18		- 8			SHARP R.ROLL
		O	C	C	8	4	1.89	61.5	24		-28	L. CENTER SECTION		R.ROLL
			C	O	8	4	1.86	62.0	25		-27	L. CENTER SECTION		R.ROLL USUALLY
			O	C	8	4	1.74	64.0	24		-29	BOTH CENTER SECTIONS	HEAVY	NO ROLL OR PITCH.
			O	O	6	4	1.92	61.0	24		-16		MED.	R.OR L.ROLL
300BHP	UP	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										
	DN	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										

VALUES ARE FOR V_{MIN} WITH STICK FULL BACK

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE IV. MODIFICATION 3. MAXWELL SLOT EXTENSION AND SMOOTH WALKWAY

POWER	FLAPS	SLOTS	HOODS	COWL FLAPS	NO. OF RUNS AVERAGED C_L	NO. OF RUNS AVERAGED α	C_L MAX.	V_L AT 4800 LBS., MPH	α WING CHORD MAX., DEG.	C.G. POSN. % M.A.C. BEFORE TAKE-OFF	APPROX. ELEV. ANGLE TO STALL, DEG. +=DN	FIRST PARTS OF WING TO STALL	BUFFETING	MOTION AT STALL AND ADDITIONAL COMMENTS
OFF	UP	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										
	DN	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C	4	4	1.92	61.0	23	32.1	-28	L.CENTER SECTION		R.ROLL
			C	O	4	4	1.85	62.5	23		-29	L.CENTER SECTION		MILD PITCH-DN. OR ABRUPT R.ROLL
			O	C	3	3	1.77	63.5	22		-29	BOTH CENTER SECTIONS	HEAVY	SHIP USUALLY PITCHED OUT,BUT ATTEMPTED CONTROL WITH SPOILERS RESULTED IN ABRUPT R.ROLL
			O	O	4	4	1.90	61.5	23		-18	CENTER SECT. AT REAR	MED.	MILD PITCH & R.ROLL
300BHP	UP	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										
	DN	C	C	C										
			C	O										
			O	C										
			O	O										
		O	C	C										
			C	O										
			O	C										
			O	O										

TABLE V. MODIFICATION 4. MAXWELL SLOT EXTENSION AND WING-ROOT FILLET

POWER	FLAPS	SLOTS	HOODS	COWL FLAPS	NO. OF RUNS AVER-AGED C_L α	C_L MAX.	V_L AT 4800 LBS., MPH	α WING CHORD MAX., DEG.	C.G. POSN. % M.A.C. BEFORE TAKE-OFF	APPROX. ELEV. ANGLE TO STALL, DEG. +=DN	FIRST PARTS OF WING TO STALL	BUFFETING	MOTION AT STALL AND ADDITIONAL COMMENTS
OFF	UP	C	C	C	4 4	1.38	72.0	18	32.5	- 6	L.INBOARD WING	MED.	R.OR L.ROLL
			C	O	4 4	1.46	70.0	19		- 6	L.WING	NONE-LT.	L.ROLL,THEN R.
			O	C	4 4	1.36	72.5	17		-13	REAR BOTH CENT.SECTIONS	MED.-HEAVY	R.ROLL,THEN L.
			O	O	4 4	1.43	71.0	20		- 8	R.WING	LT.	R.ROLL,THEN L.
		O	C	C	3 3	1.61	66.5	23		-15	L.CENTER SECTION	LT.	PITCH-DN,IF HELD WILL ROLL ABRUPTLY R.
			C	O	4 4	1.73	64.5	28		-22	L.CENTER SECTION	MED.	PITCH-DN,WITH R.ROLL SOMETIMES
			O	C	4 4	1.63	66.5	29		-29	REAR BOTH CENT.SECTIONS	MED.-HEAVY	R.ROLL. BUFFETING STARTS EARLY
			O	O	4 4	1.76	64.0	26		-21	EXTREME REAR CENT. SECT.	NONE-LT.	R.ROLL
	DN	C	C	C	4 4	1.84	62.5	16		- 6	INBOARD L.WING	LT.	MILD L.ROLL
			C	O	4 4	1.91	61.5	17		- 6	INBOARD L. WING	NONE-LT.	MILD L.ROLL
			O	C	4 4	1.76	64.0	15		-18	REAR L.CENTER SECTION	LT.	L.ROLL
			O	O	4 4	1.94	61.0	20		- 9	BOTH WINGS	NONE-LT.	MILD PITCH-DN
		O	C	C	4 4	1.92	61.0	23		-28	L.CENTER SECTION	MED.	ABRUPT R.ROLL
			C	O	4 4	2.01	59.5	26		-29	L.CENTER SECTION	MED.	ABRUPT R.ROLL
			O	C	4 4	1.86	62.0	21		-28	BOTH CENTER SECTIONS	HEAVY	MILD PITCH-DN OR VIOLENT L.ROLL
			O	O	4 4	1.97	60.5	21		-12	REAR OF CENTER SECTIONS	LT.	MILD L.OR R.ROLL
300BHP	UP	C	C	C	4 4	1.73	64.5	21		- 3	R.WING	NONE	R.,THEN L.,THEN R.
			C	O	4 4	1.78	63.5	21		- 2	R.WING	NONE	R.,THEN L.,THEN R.
			O	C	4 4	1.76	64.0	20		- 3	R.WING	NONE	R.,THEN L.,THEN R.
			O	O	4 4	1.79	63.5	20		- 2	R.WING	NONE	R.,THEN L.,THEN R.
		O	C	C	4 4	2.18	57.5	27		- 6	R.OUTBOARD WING	NONE	R.ROLL.CONSIDERABLE R.SLIP
			C	O	4 4	2.26	56.0	27		- 6	R.OUTBOARD WING	NONE	R.ROLL.CONSIDERABLE R.SLIP
			O	C	4 4	2.18	57.5	27		- 9	R.OUTBOARD WING	NONE	R.ROLL.CONSIDERABLE R.SLIP
			O	O	4 4	2.22	56.5	25		- 7	R.OUTBOARD WING	NONE	R.ROLL. CONSIDERABLE R.SLIP
	DN	C	C	C	4 4	2.68	51.5	21		+ 2	L.WING	NONE	L.ROLL OR PITCH-DN
			C	O	4 4	2.82	50.5	19		+ 3	L.WING	NONE	L.ROLL OR PITCH-DN
			O	C	4 4	2.70	51.5	21		+ 2	L.WING	NONE	MILD L.ROLL
			O	O	4 4	2.77	51.0	20		+ 4	BOTH WINGS	NONE	PITCH-DN
		O	C	C	4 4	2.88	50.0	25		- 1	L.WING,THEN R.	NONE	R.ROLL
			C	O	4 4	3.03	48.5	24		+ 3	L.WING,THEN R.	NONE	R.ROLL
			O	C	4 4	2.86	50.0	25		+ 1	L.WING,THEN R.	NONE	R.ROLL. MUCH R.SIDESLIP.LARGE ALTITUDE LOSS
			O	O	4 4	3.00	49.0	25		+ 3	L.WING.THEN R.	NONE	R.ROLL OR PITCH-DN
OFF	DN	O	O	C	4 4	1.82	63.0	—		-29	BOTH CENTER SECTIONS	MED.	PITCH-DN
			O	O¼	4 4	1.80	63.0	—		-29	BOTH CENTER SECTIONS	MED.	PITCH-DN OR R.ROLL
			O	O½	4 4	1.82	63.0	—		-29	BOTH CENTER SECTIONS	MED.	R.ROLL
			O	O¾	4 4	1.94	61.0	—		-23	BOTH CENTER SECTIONS	MED.	R.OR L.ROLL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE VI. MODIFICATION 5. WING-ROOT FILLET ONLY

POWER	FLAPS	SLOTS	HOODS	COWL FLAPS	NO. OF RUNS AVER-AGED	C_L MAX.	V_L	α	C.G. POSN.	ELEV. ANGLE	FIRST PARTS OF WING TO STALL	BUFFETING	MOTION AT STALL AND ADDITIONAL COMMENTS
OFF	UP	C	C	C	4 4	1.34	73.0	18	32.5	- 6	L.INBOARD WING	MED.	L.ROLL,THEN R. MILD
			C	O	4 4	1.37	72.5	18		- 5	REAR INB'D WINGS & CENT.SECT.	MED.	R.ROLL,THEN L.
			O	C	4 4	1.31	74.0	19		-15	BOTH CENTER SECTIONS	MED.	R.ROLL
			O	O	4 4	1.39	72.0	19		- 8	R.OUTBOARD WING	MED.	R.ROLL
		O	C	C	4 4	1.55	68.0	23		-27	BOTH CENTER SECTIONS	HEAVY	PITCH-DN & MILD OSCILLATION IN ROLL & YAW
			C	O	4 4	1.41	71.5	23		-28	BOTH CENTER SECTIONS	HEAVY	PITCH-DN & MILD OSCILLATION IN ROLL & YAW
			O	C	4 4	1.59	67.5	28		-29	BOTH CENTER SECTIONS	HEAVY	PITCH-DN & MILD OSCILLATION IN ROLL & YAW
			O	O	4 4	1.45	70.5	22		-24	BOTH CENTER SECTIONS	HEAVY	PITCH-DN & MILD OSCILLATION IN ROLL & YAW
	DN	C	C	C	4 4	2.05	59.0	16		- 6	L.CENTER SECT.& WING	LT.-MED.	L.ROLL,THEN R.,OR L.ROLL & PITCH-DN
			C	O	4 4	1.89	61.5	15		- 6	R.CENTER SECT.& WING	LT.-MED.	R.ROLL & PITCH-DN
			O	C	4 4	1.74	64.0	18		-24	BOTH CENTER SECTIONS	LT.-MED.	PITCH-DN.GENTLE STALL
			O	O	4 4	1.92	61.0	18		- 9	L.WING & CENTER SECTION	LT.	L.ROLL
		O	C	C	4 4	1.71	64.5	18		- 8	L.CENTER SECTION	MED.	L.ROLL
			C	O	4 4	1.65	66.0	17		- 8	L.CENTER SECTION	MED.	ROLLING OSCILLATION
			O	C	4 4	1.72	64.5	20		-29	BOTH CENTER SECTIONS	LT.-MED.	SLIGHT ROLLING OSCILLATION,THEN PITCH-DN
			O	O	4 4	1.76	64.0	19		-29	L.CENTER SECTION	LT.-MED.	PITCH-DN
300BHP	UP	C	C	C									
			C	O									
			O	C									
			O	O									
		O	C	C									
			C	O									
			O	C									
			O	O									
	DN	C	C	C									
			C	O									
			O	C									
			O	O									
		O	C	C									
			C	O									
			O	C									
			O	O									

TABLE VII. MODIFICATION 6. LOWER FLAP GAP SEALED

POWER	FLAP	SLOT	HOODS	COWL FLAPS	NO. OF RUNS AVERAGED C_L	NO. OF RUNS AVERAGED α	C_L MAX.	V_L AT 4800 LBS., MPH	α WING CHORD MAX., DEG.	C.G. POSN. % M.A.C. BEFORE TAKE-OFF	APPROX. ELEV. ANGLE TO STALL, DEG. +=DN	FIRST PARTS OF WING TO STALL	BUFFETING	MOTION AT STALL AND ADDITIONAL COMMENTS
OFF	UP	C	C	C										
↓	↓	↓	C	O										
↓	↓	↓	O	C										
↓	↓	↓	O	O										
↓	↓	O	C	C										
↓	↓	↓	C	O										
↓	↓	↓	O	C										
↓	↓	↓	O	O										
↓	DN	C	C	C	4	0	1.64	66.0	—	32.5	-10	EITHER WING	MED.	L.OR R.ROLL
↓	↓	↓	C	O	5	0	1.66	65.5	—	↓	- 9.5	R.WING	MED.	L. ROLL
↓	↓	↓	O	C	4	0	1.69	65.0	—	↓	-18.5	PROBABLY INB'D EITHER WING	MED.	L.OR R.ROLL OR PITCH-DN.
↓	↓	↓	O	O	5	0	1.77	63.5	—	↓	- 6.5	L. OUTBOARD	LT.	L.ROLL
↓	↓	O	C	C										
↓	↓	↓	C	O										
↓	↓	↓	O	C										
↓	↓	↓	O	O										
300BHP	UP	C	C	C										
↓	↓	↓	C	O										
↓	↓	↓	O	C										
↓	↓	↓	O	O										
↓	↓	O	C	C										
↓	↓	↓	C	O										
↓	↓	↓	O	C										
↓	↓	↓	O	O										
↓	DN	C	C	C										
↓	↓	↓	C	O										
↓	↓	↓	O	C										
↓	↓	↓	O	O										
↓	↓	O	C	C										
↓	↓	↓	C	O										
↓	↓	↓	O	C										
↓	↓	↓	O	O										

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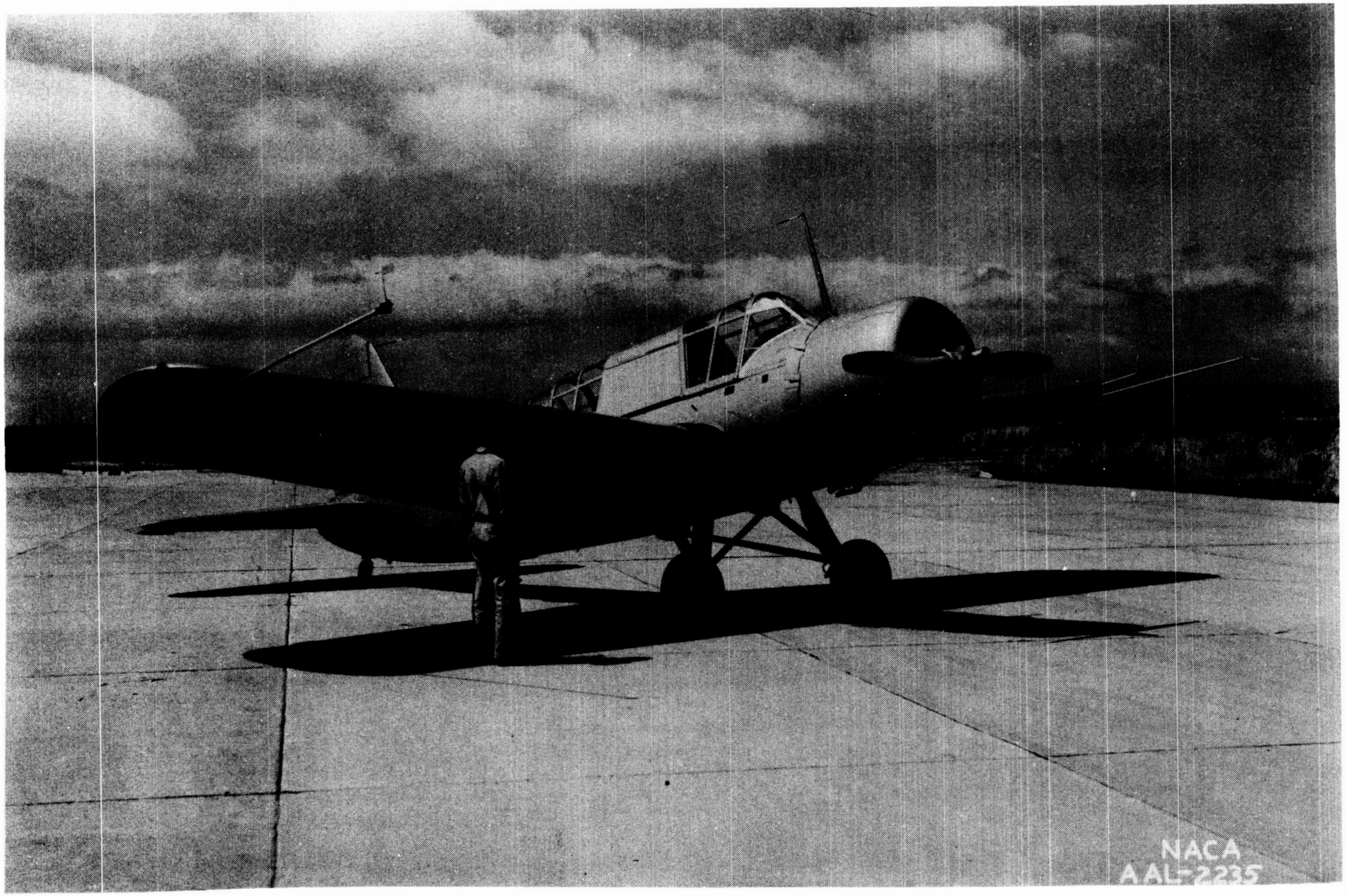

Figure 1.- Three-quarter front view of the test airplane as instrumented for flight tests.

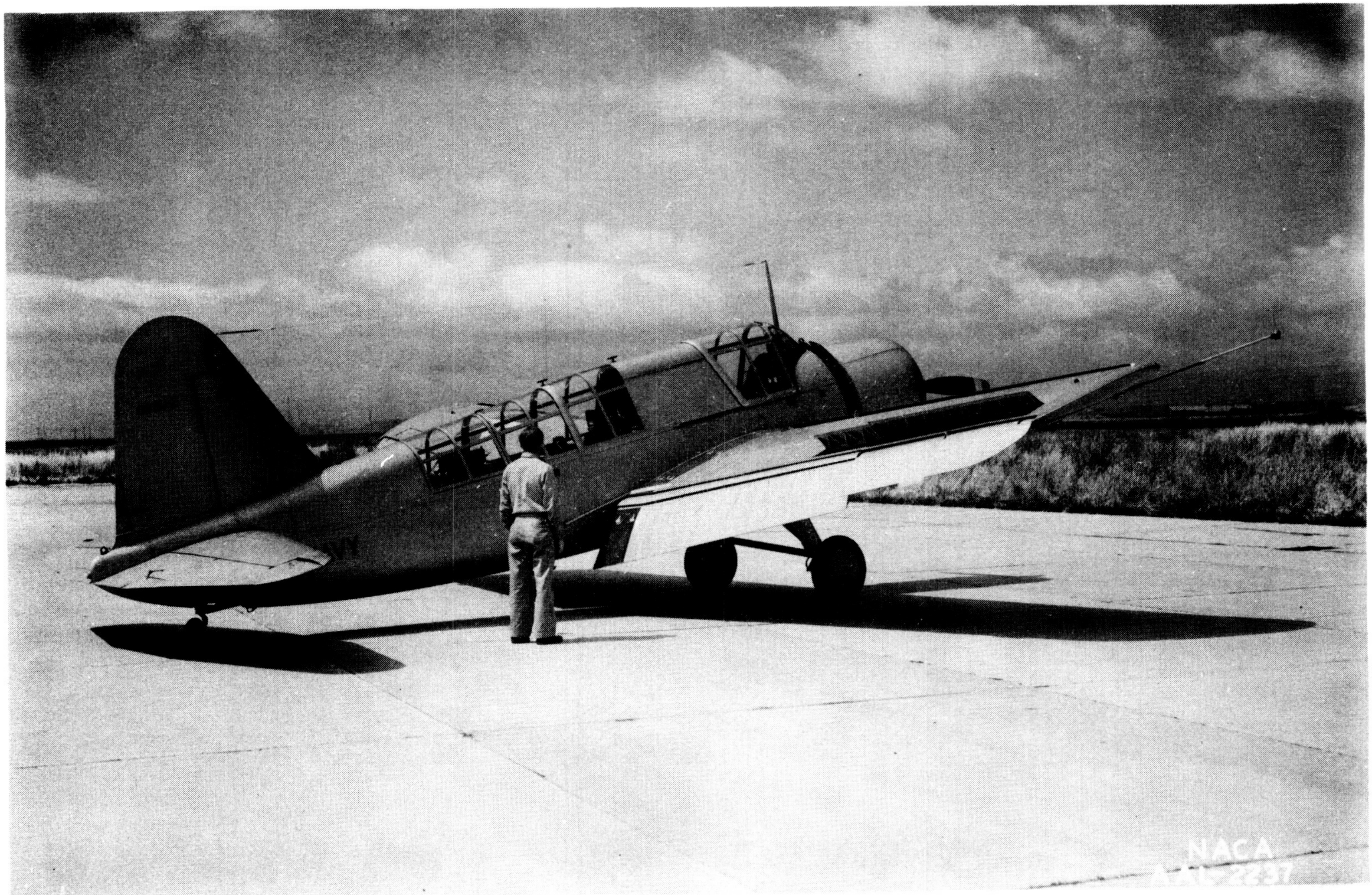

Figure 2.- Three-quarter rear view of the test airplane as instrumented for flight tests, showing deflected flap, drooped aileron, deflected spoiler, and open slot.

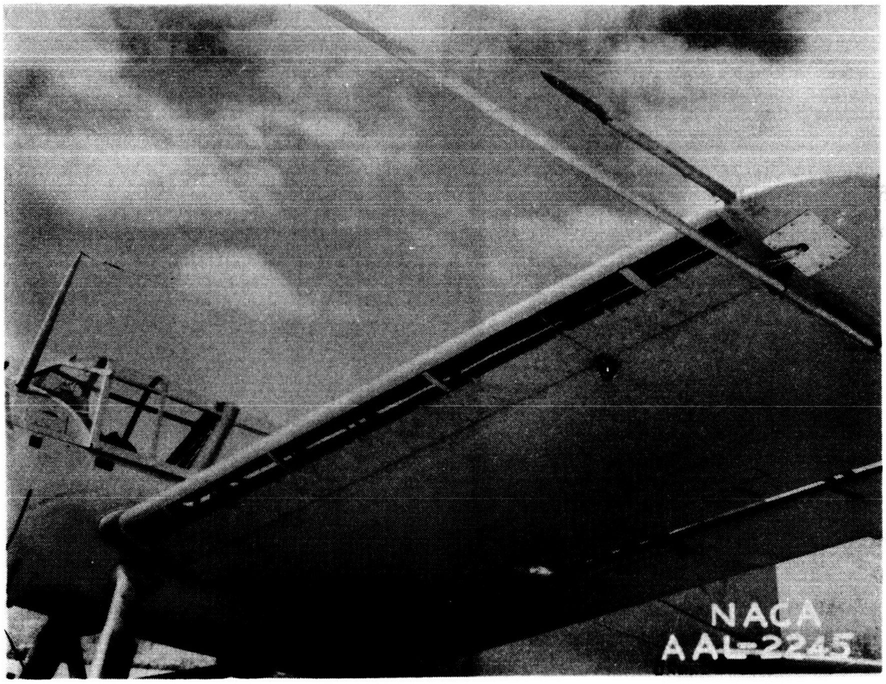

Figure 3.- Detail of Maxwell slot installation, slots open. Spoiler paddle balance is also visible flush with wing ahead of aileron.

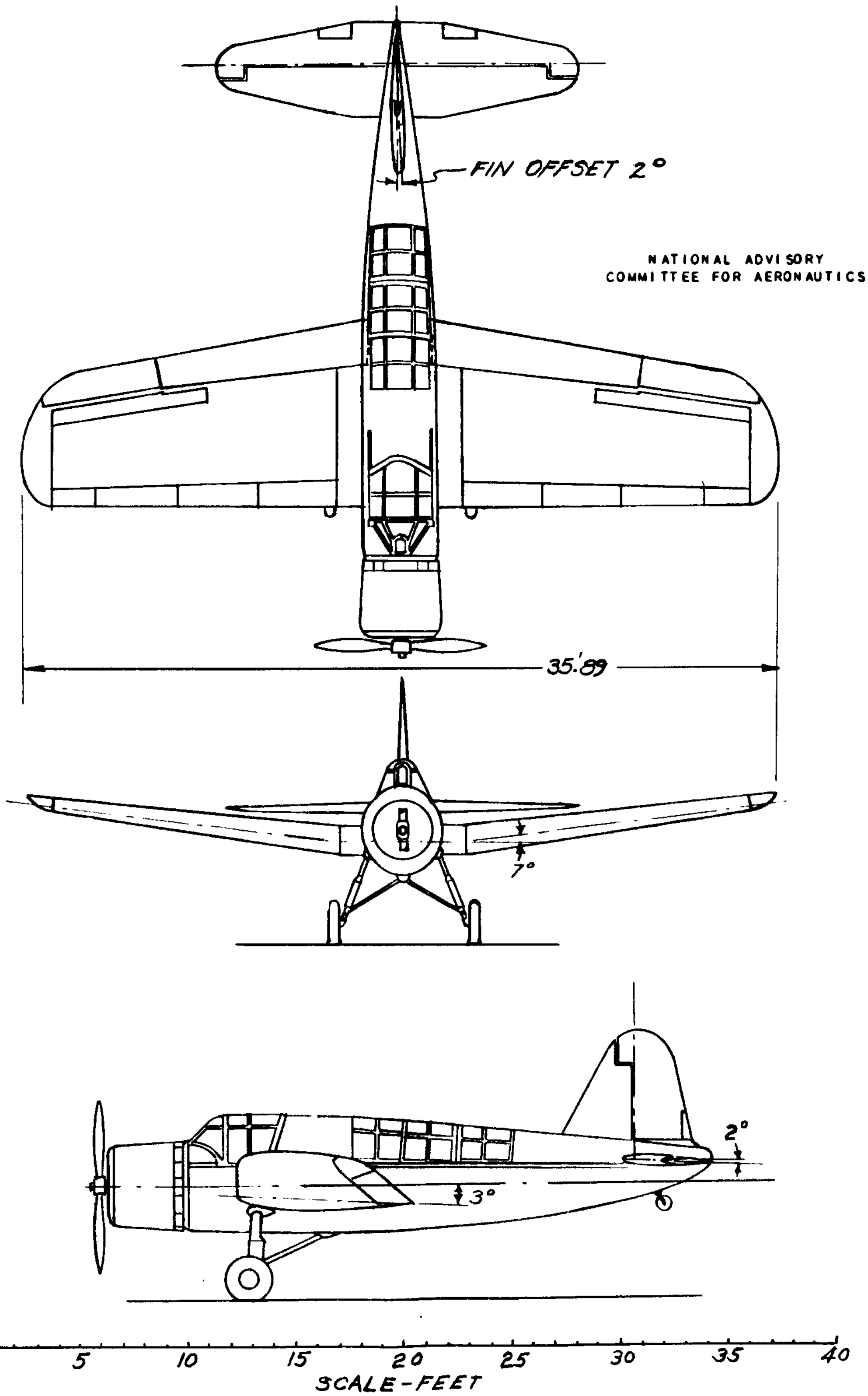

FIGURE 4. - THREE-VIEW DRAWING OF TEST AIRPLANE.

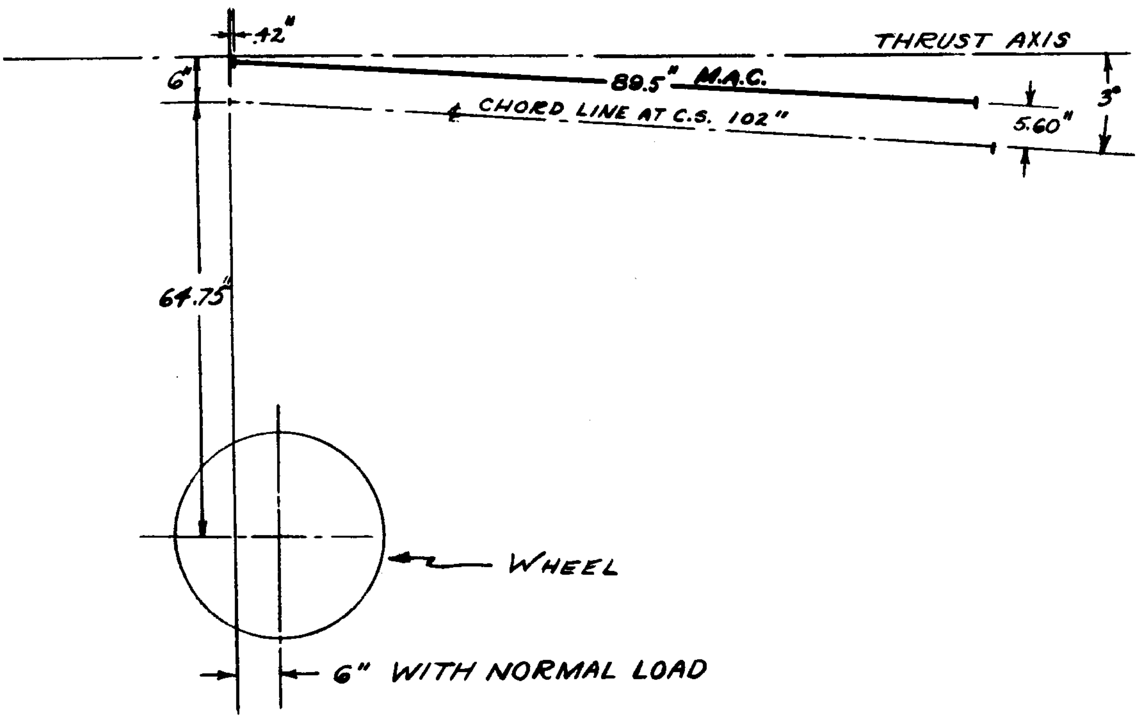

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Figure 5.- Sketch showing location of mean aerodynamic chord on test airplane.

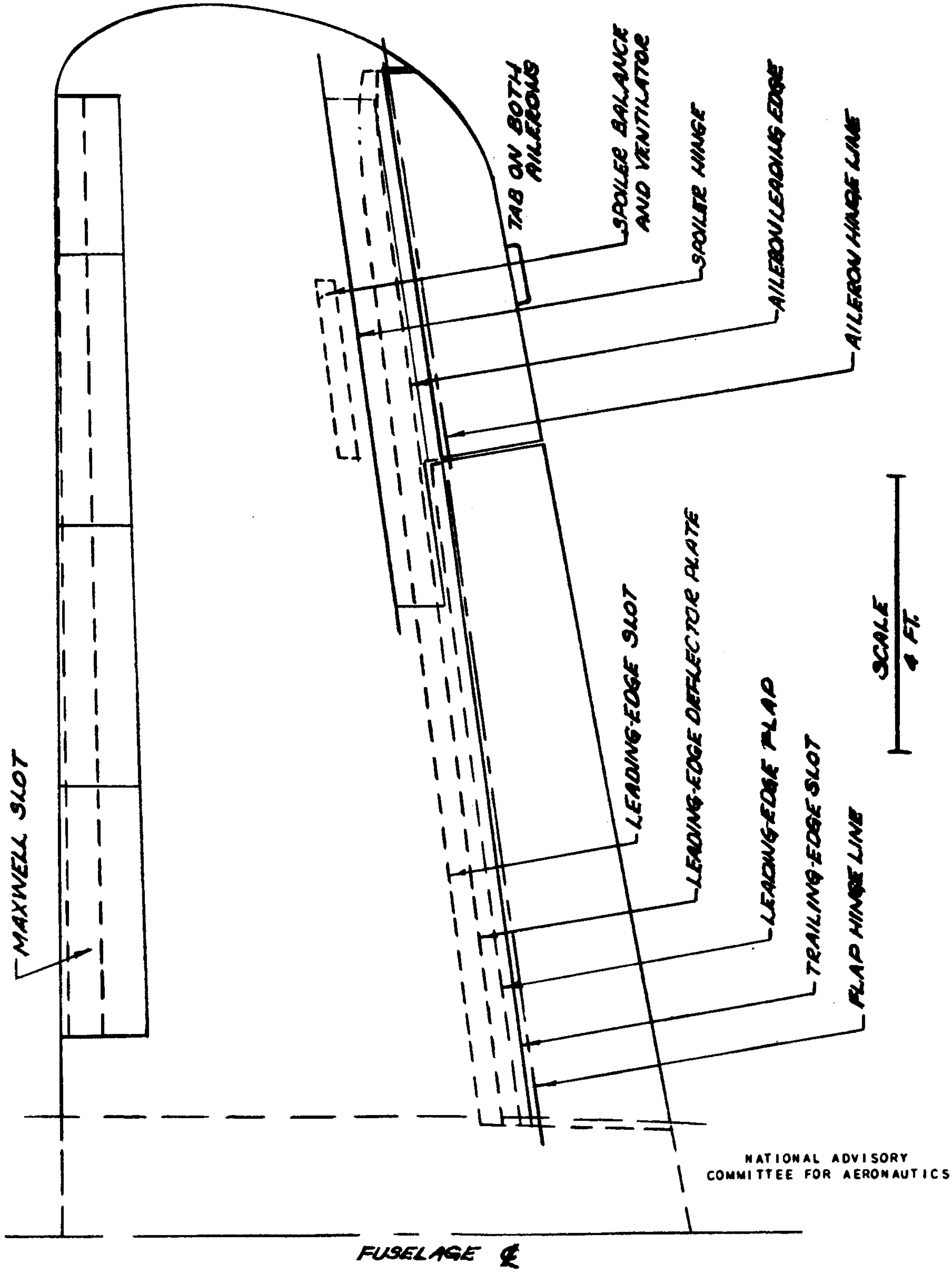

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Figure 6.- Plan view showing high-lift and lateral-control devices of test airplane.

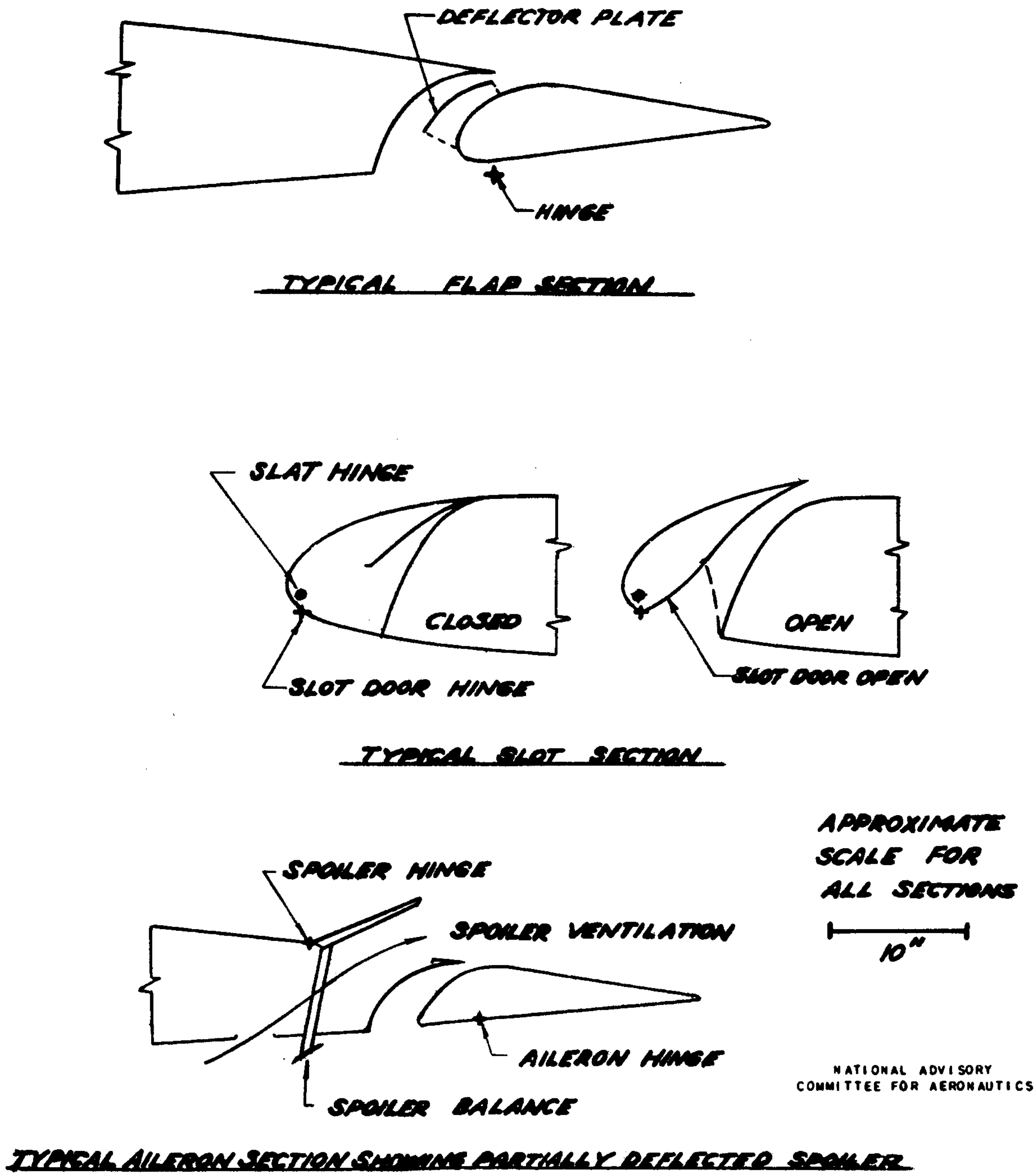


Figure 7.- Typical sections of high-lift and lateral-control devices of test airplane.

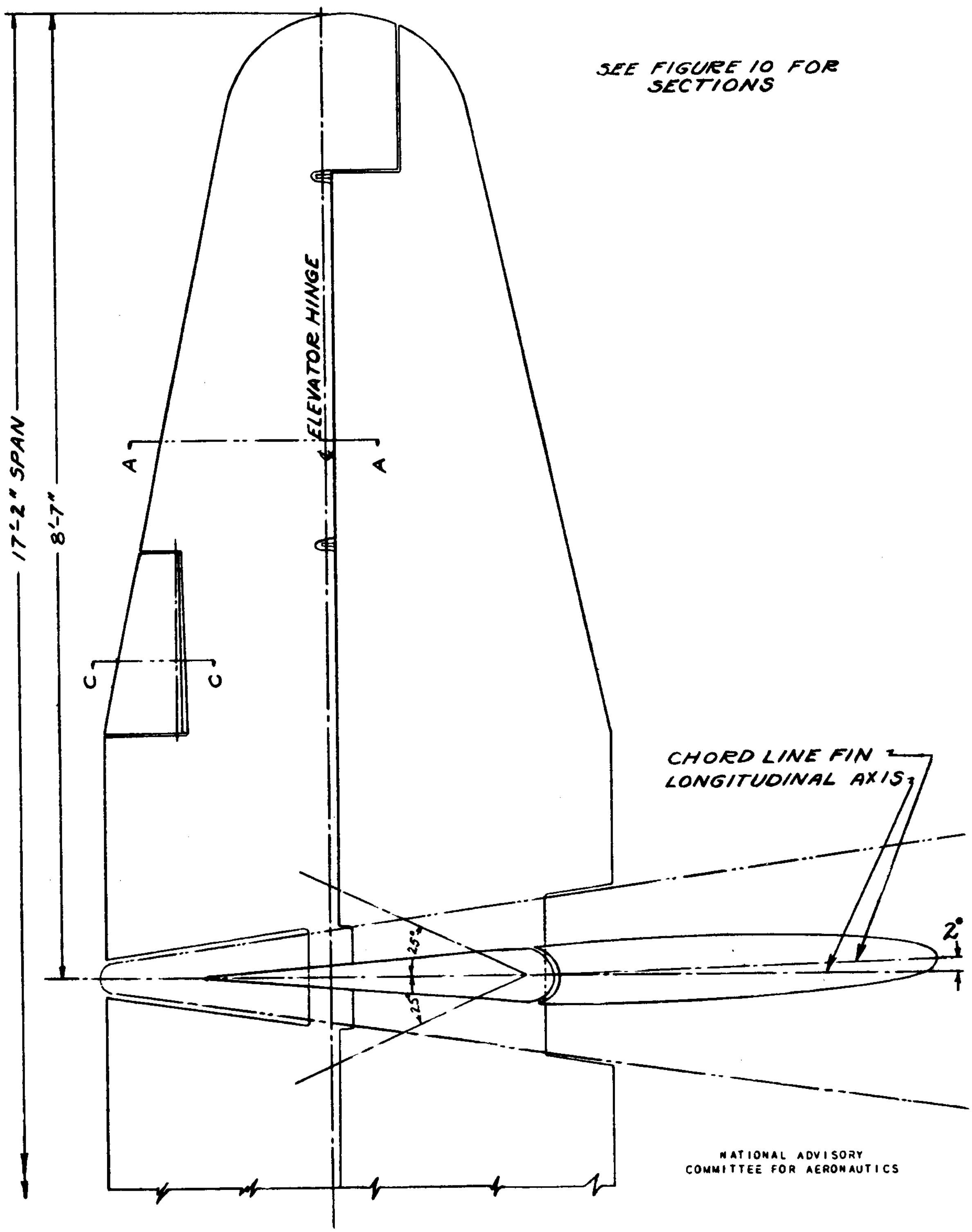


Figure 8.- Plan view of the horizontal tail on the test airplane.

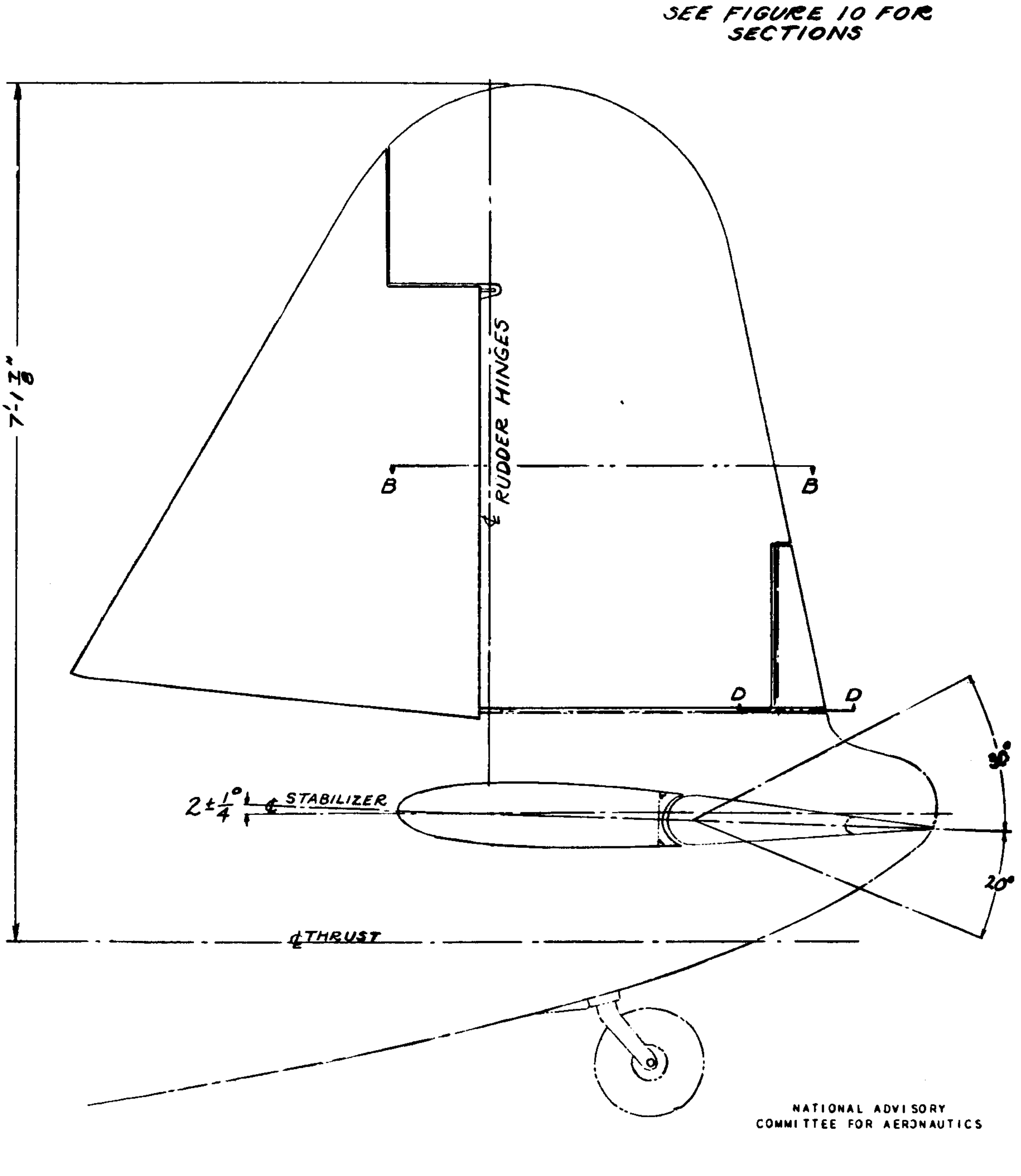


Figure 9.- Side view of the vertical tail of the test airplane.

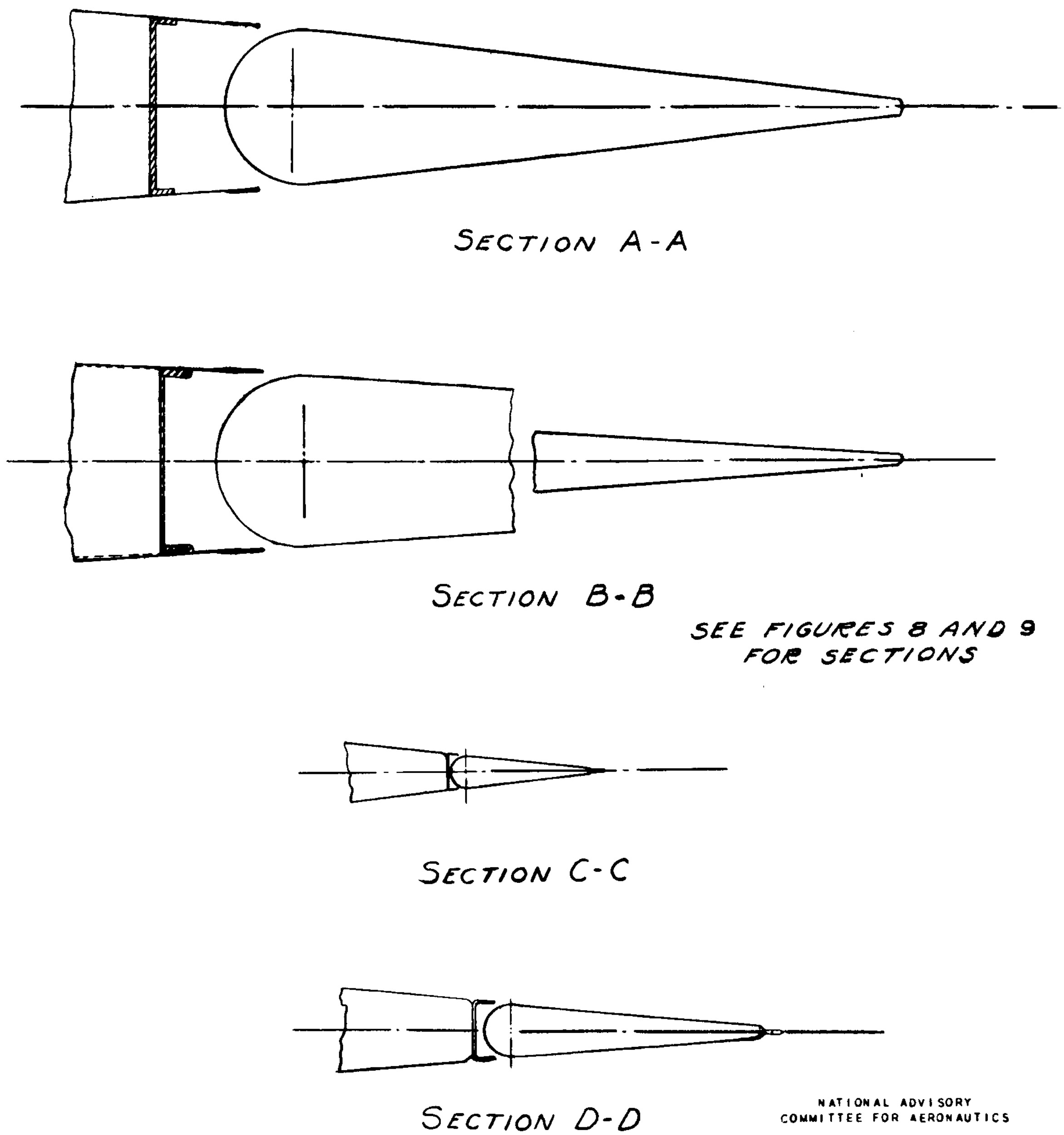


Figure 10.- Section views of empennage control surfaces and tabs on test airplane.

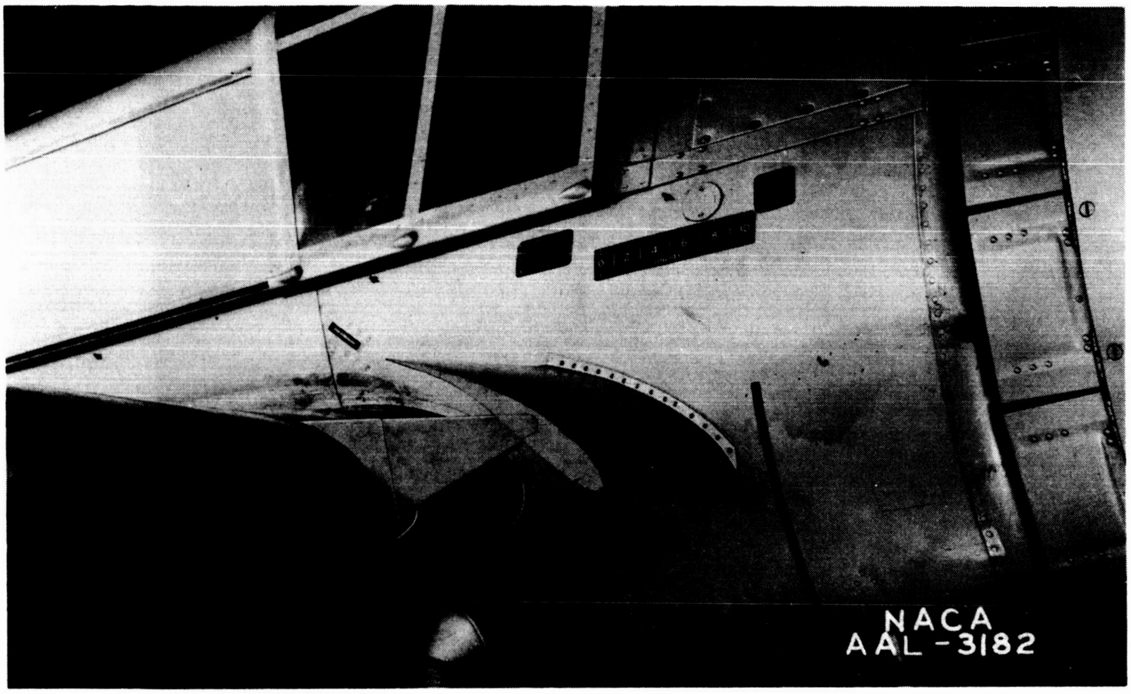
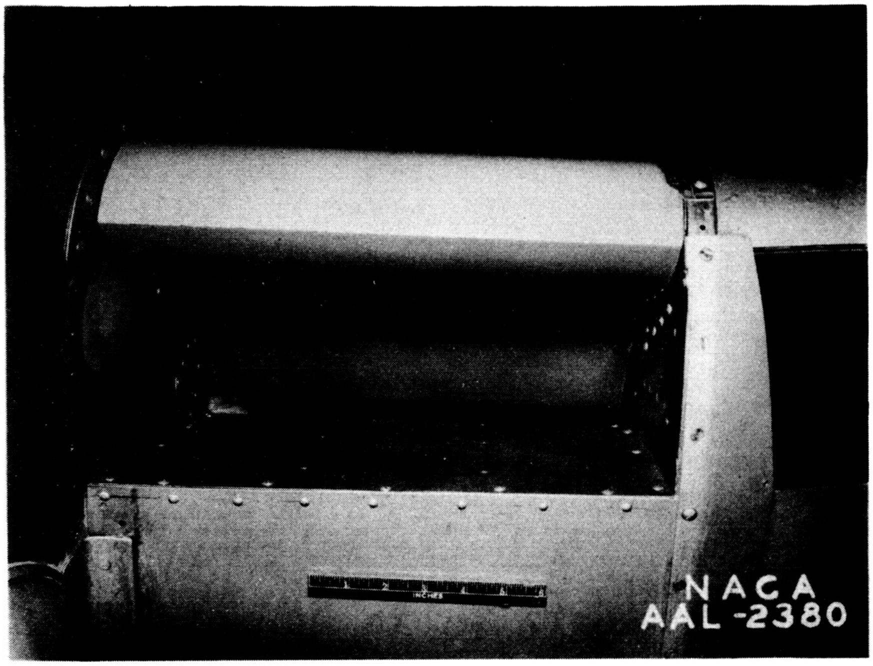


Figure 11.- Auxiliary slat installed on test airplane.



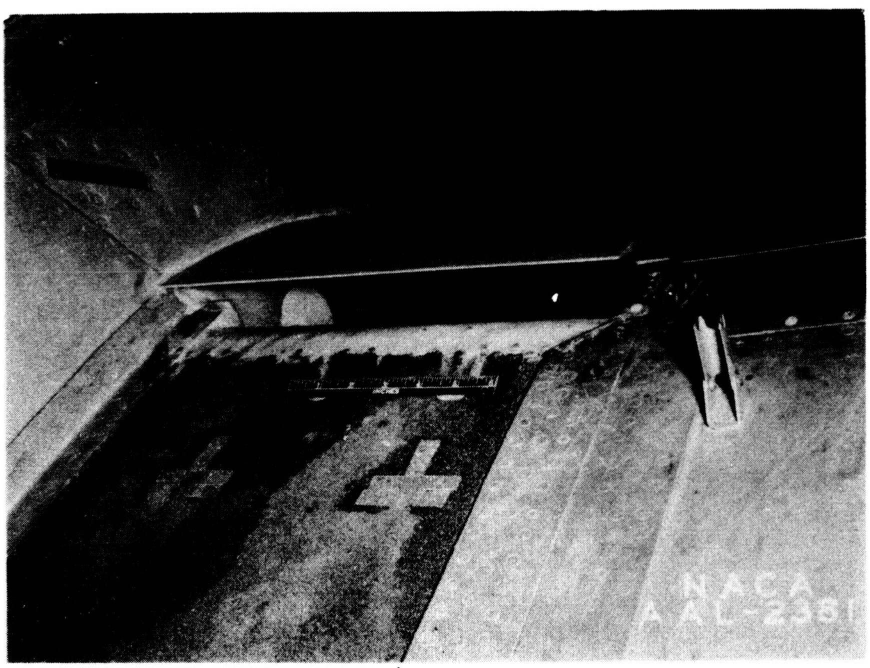


Figure 12.- Lower front and upper rear views through Maxwell slot extension.

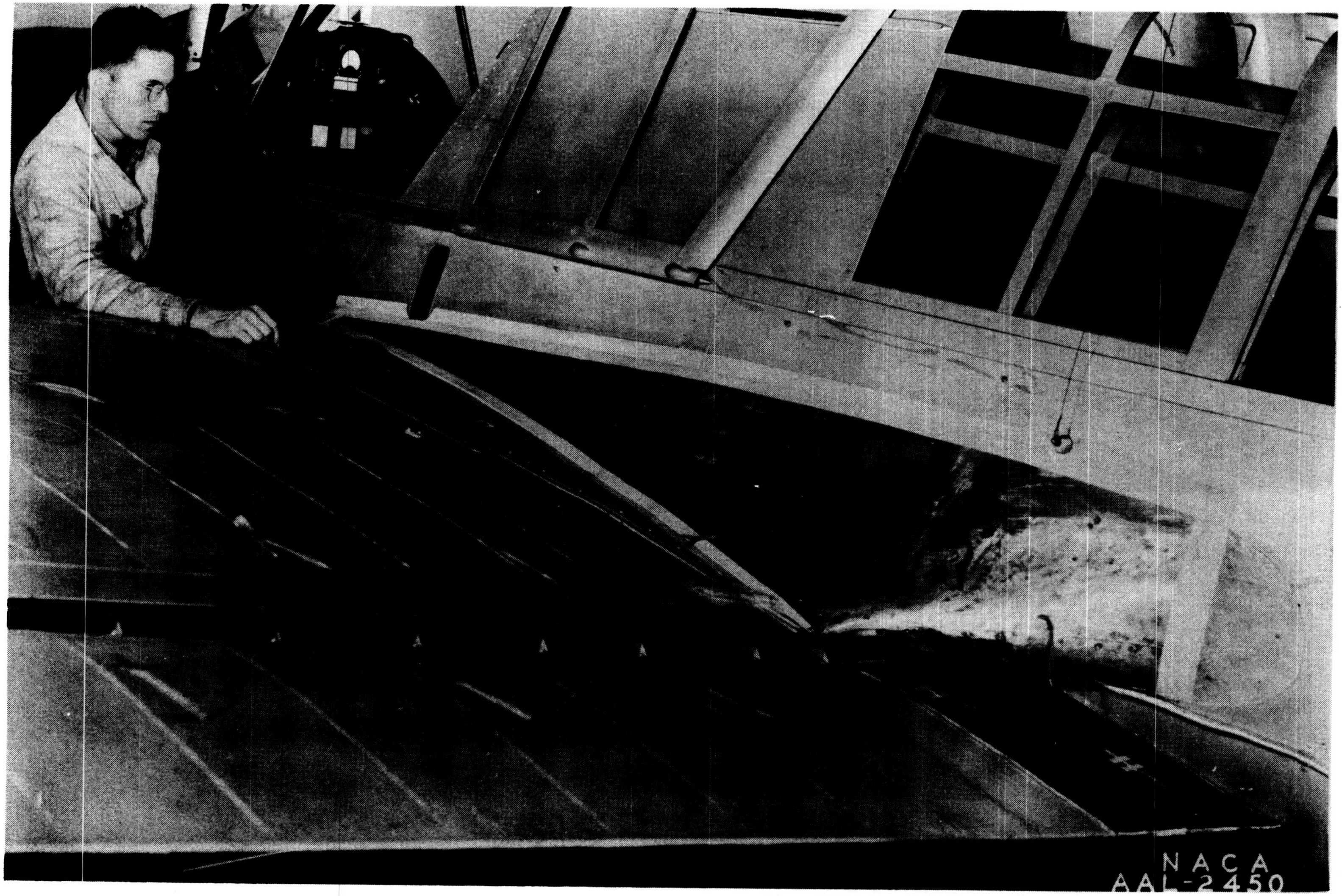


Figure 13.- Wing-root fillet.

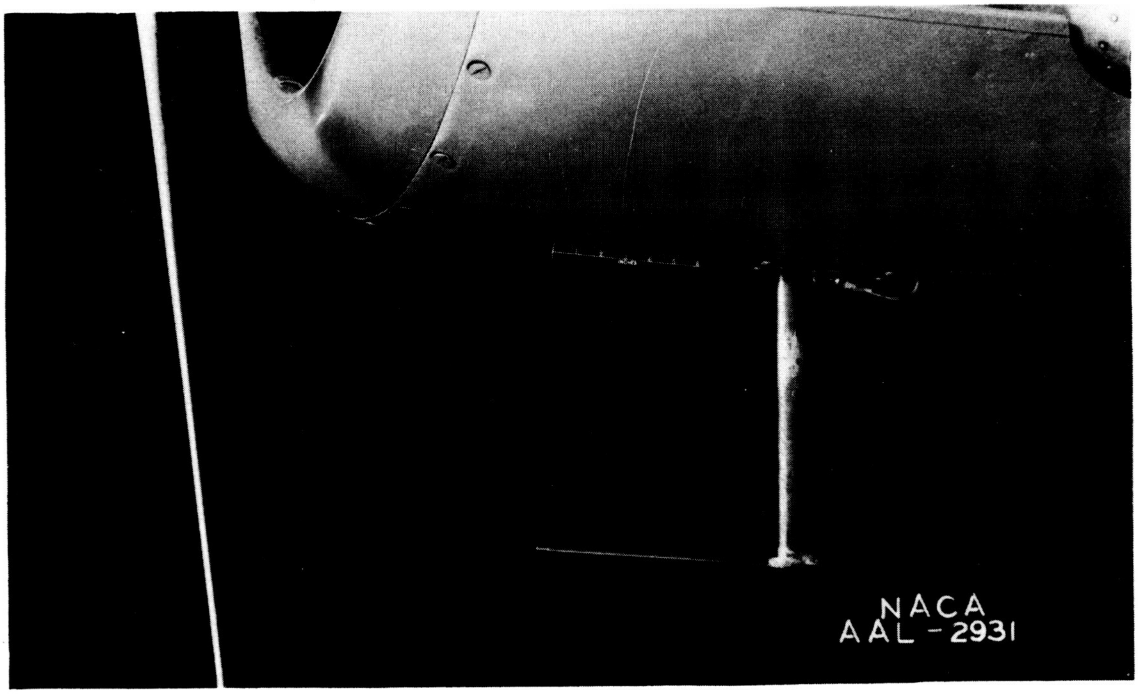


Figure 14.- Slipstream total-pressure tube.

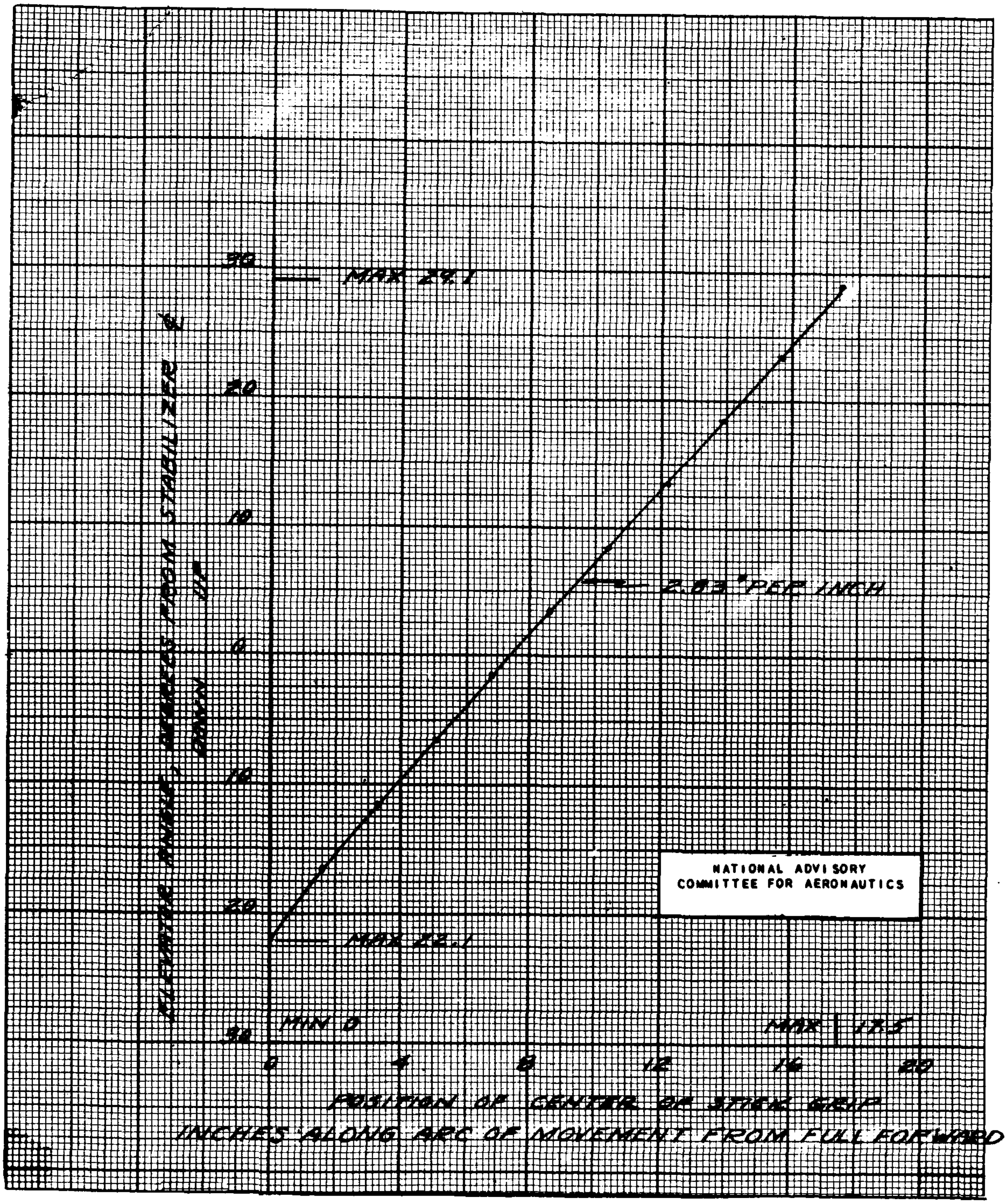


Figure 15.- Variation of elevator angle with stick position as measured on the ground with no load on the surfaces.

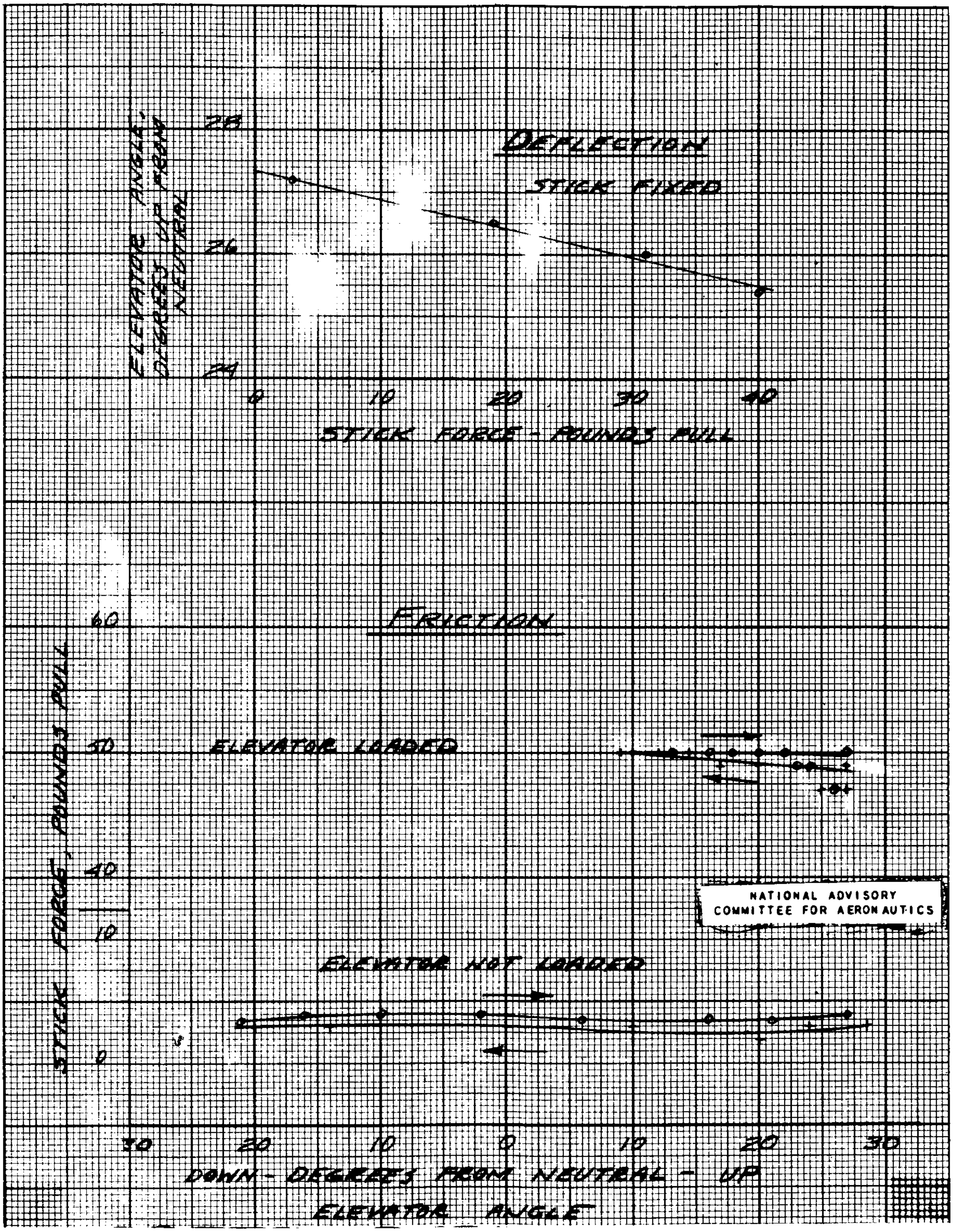


Figure 16.- Friction and deflection in the elevator control system as measured on the ground.

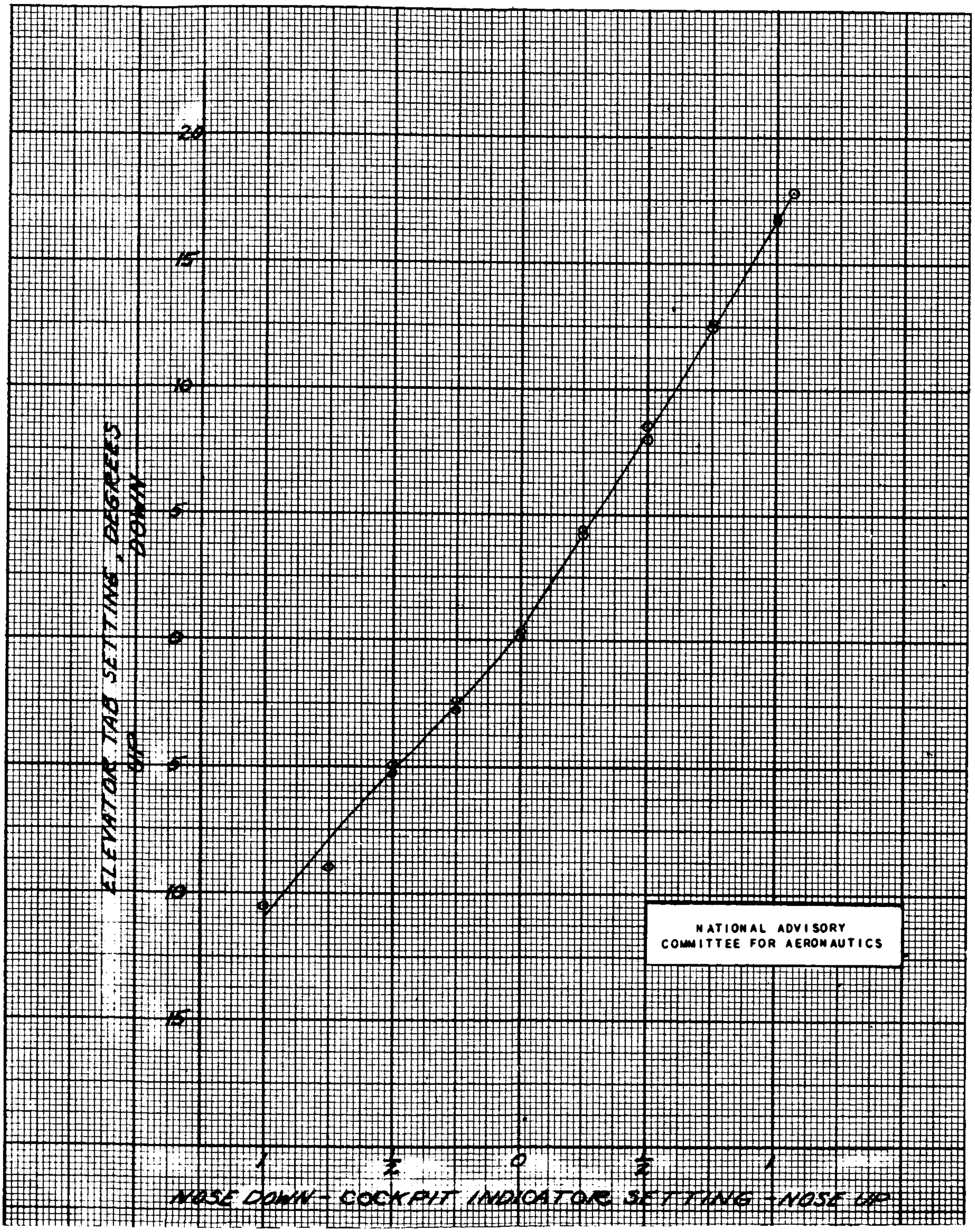


Figure 17.- Variation of elevator tab position with cockpit control setting.

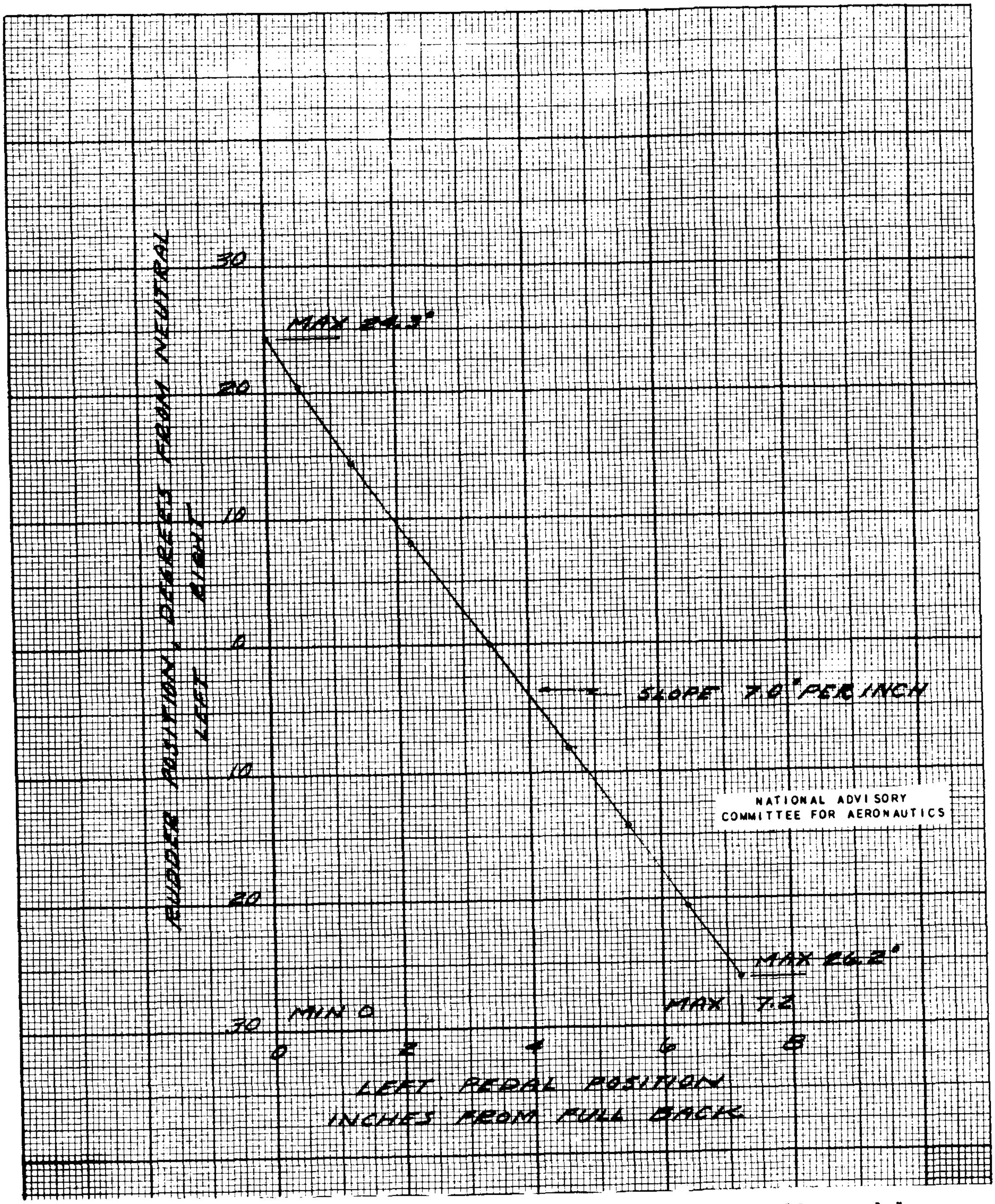


Figure 18.- Variation of rudder angle with left rudder pedal position as measured on the ground with no load on the surfaces.

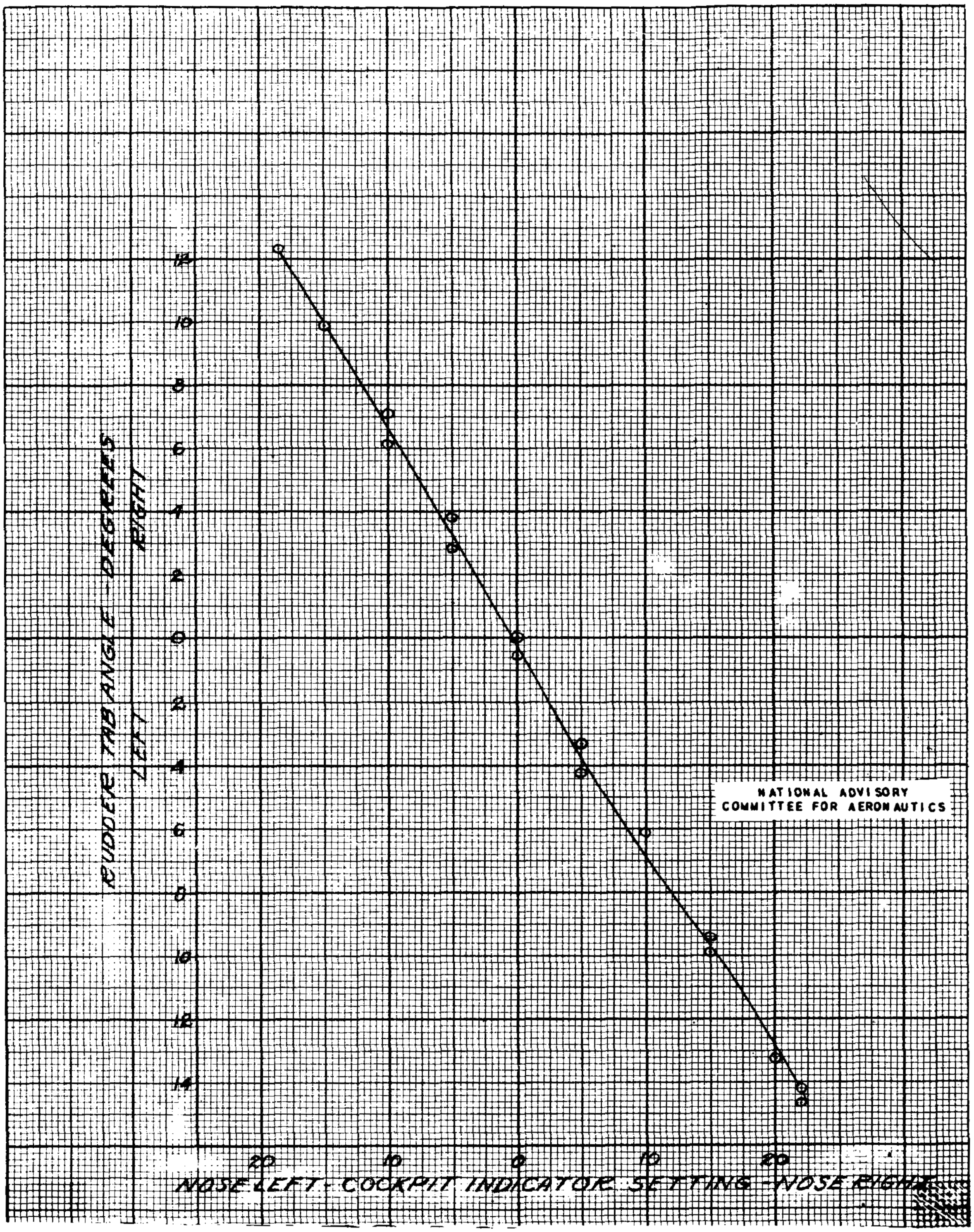


Figure 19.- Variation of rudder tab angle with cockpit control setting.

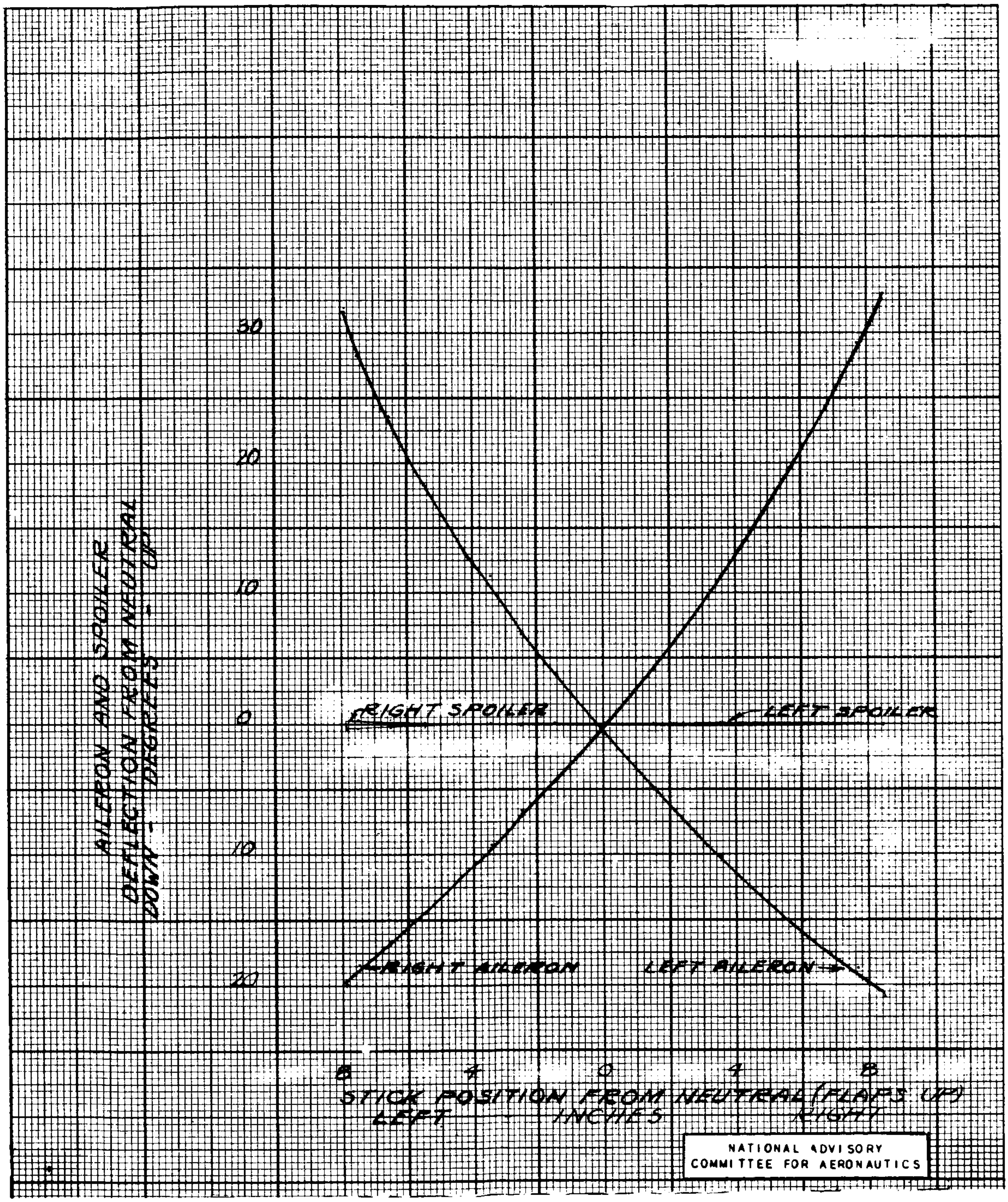


Figure 20.- Variation of aileron and spoiler angles with stick position as measured on the ground with no load on the surfaces. Test airplane with flaps up.

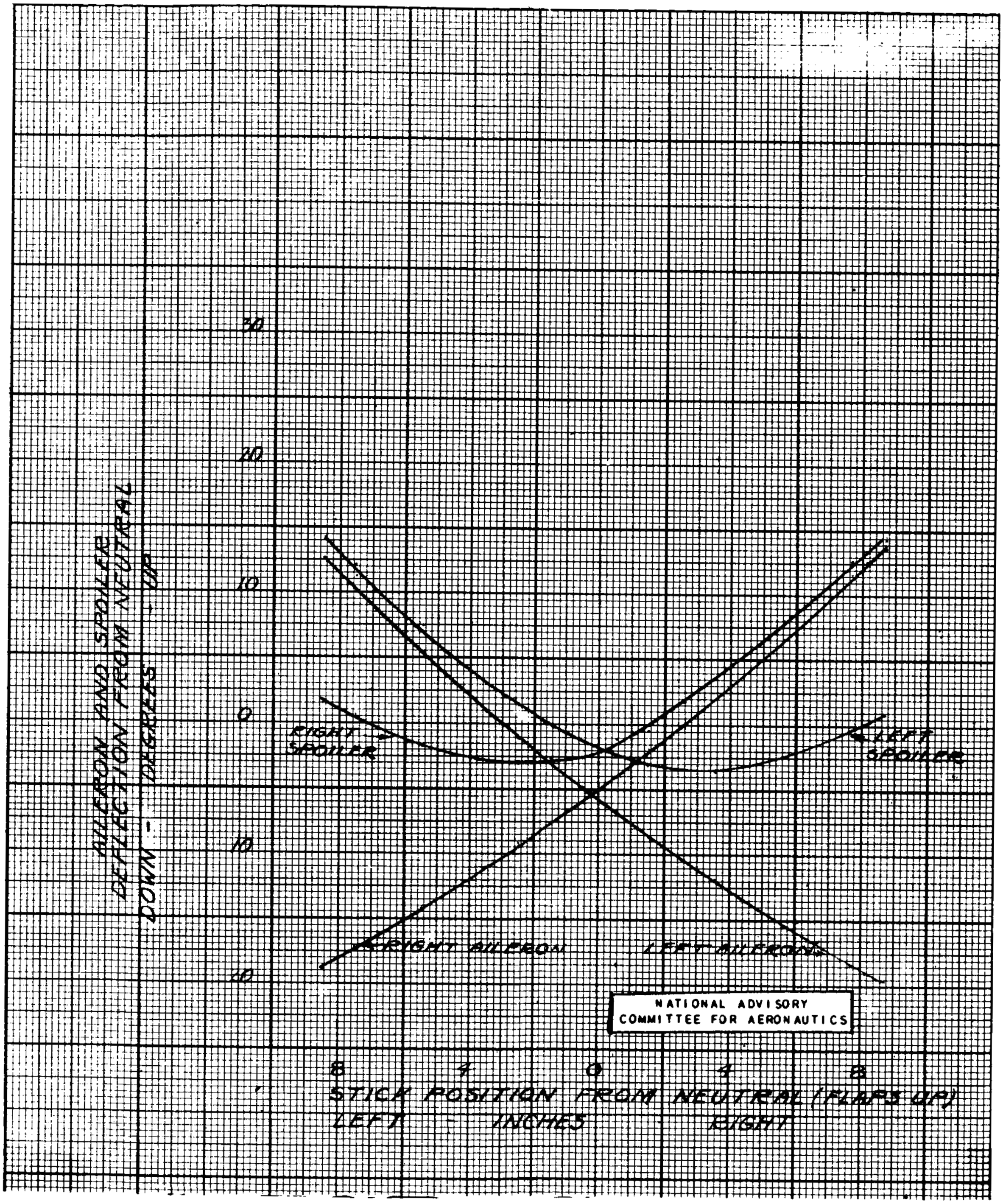


Figure 21.- Variation of aileron and spoiler angles with stick position as measured on the ground with no load on the surfaces. Test airplane with flaps 1/3 down.

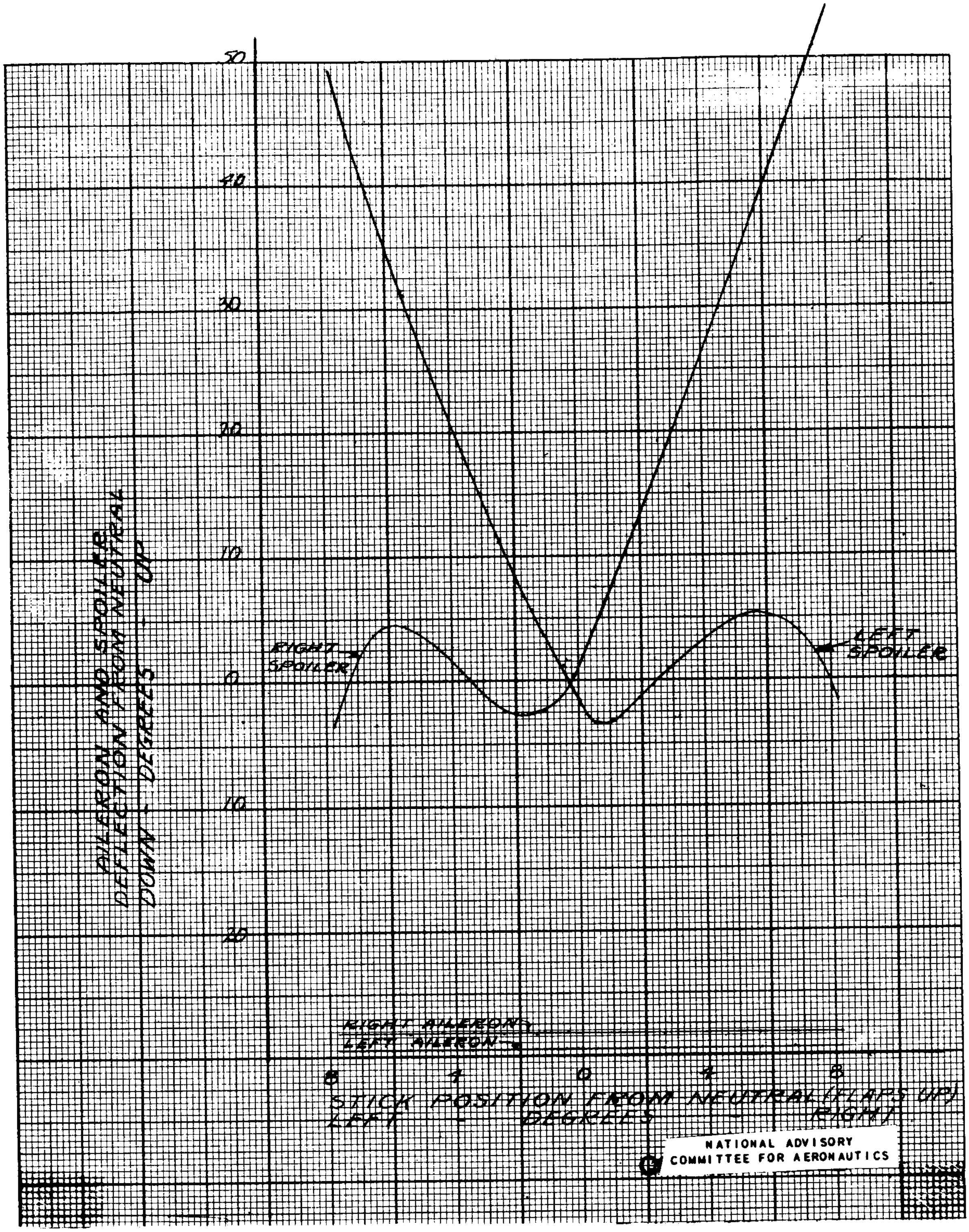


Figure 22.- Variation of aileron and spoiler angles with stick position as measured on the ground with no load on the surfaces. Test airplane with flaps full down.

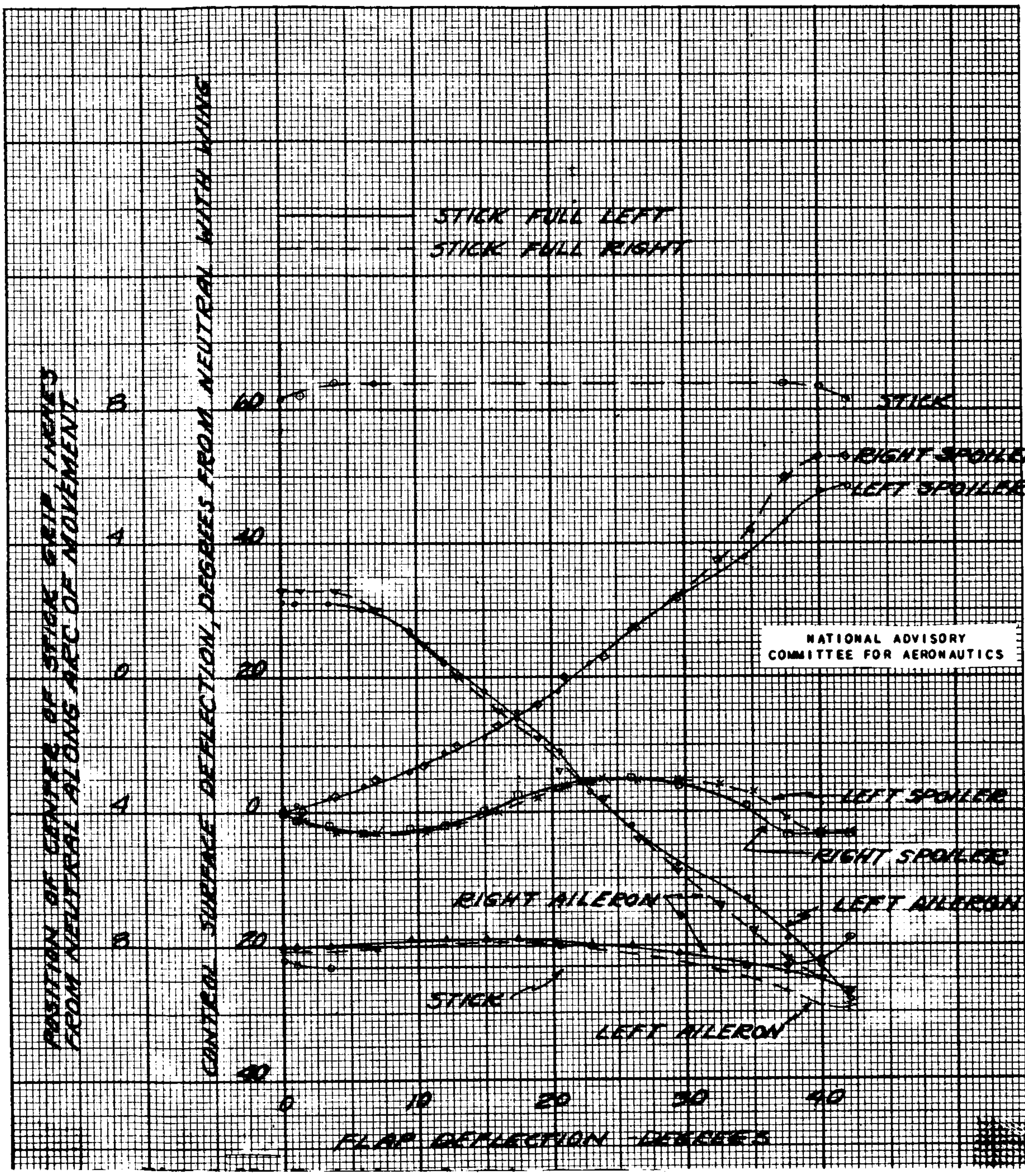


Figure 23.- Variation of maximum movements of ailerons and spoilers with change in flap position.

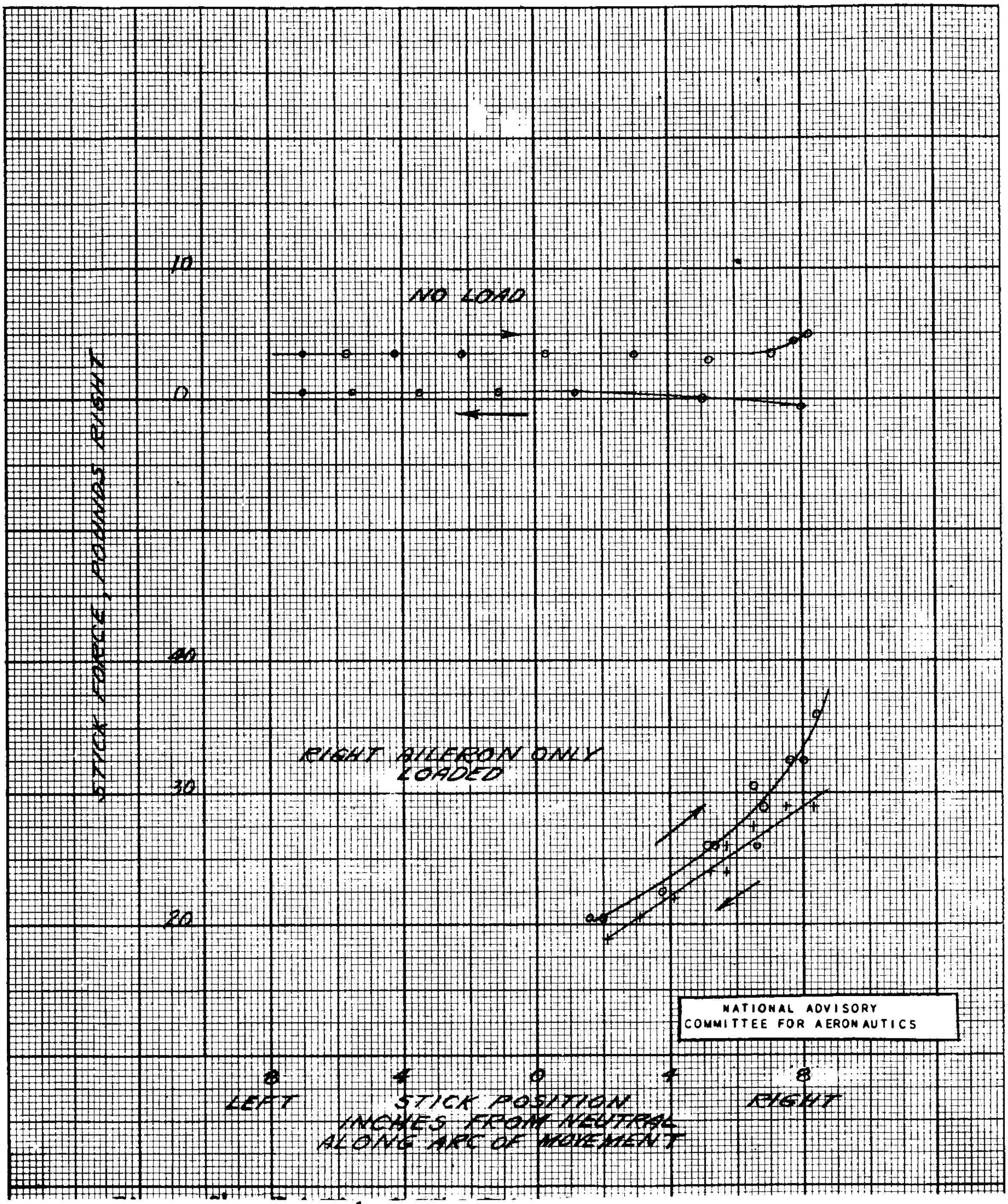


Figure 24.- Friction in the lateral control system, flaps up, as indicated by the stick force required to move the controls on the ground.

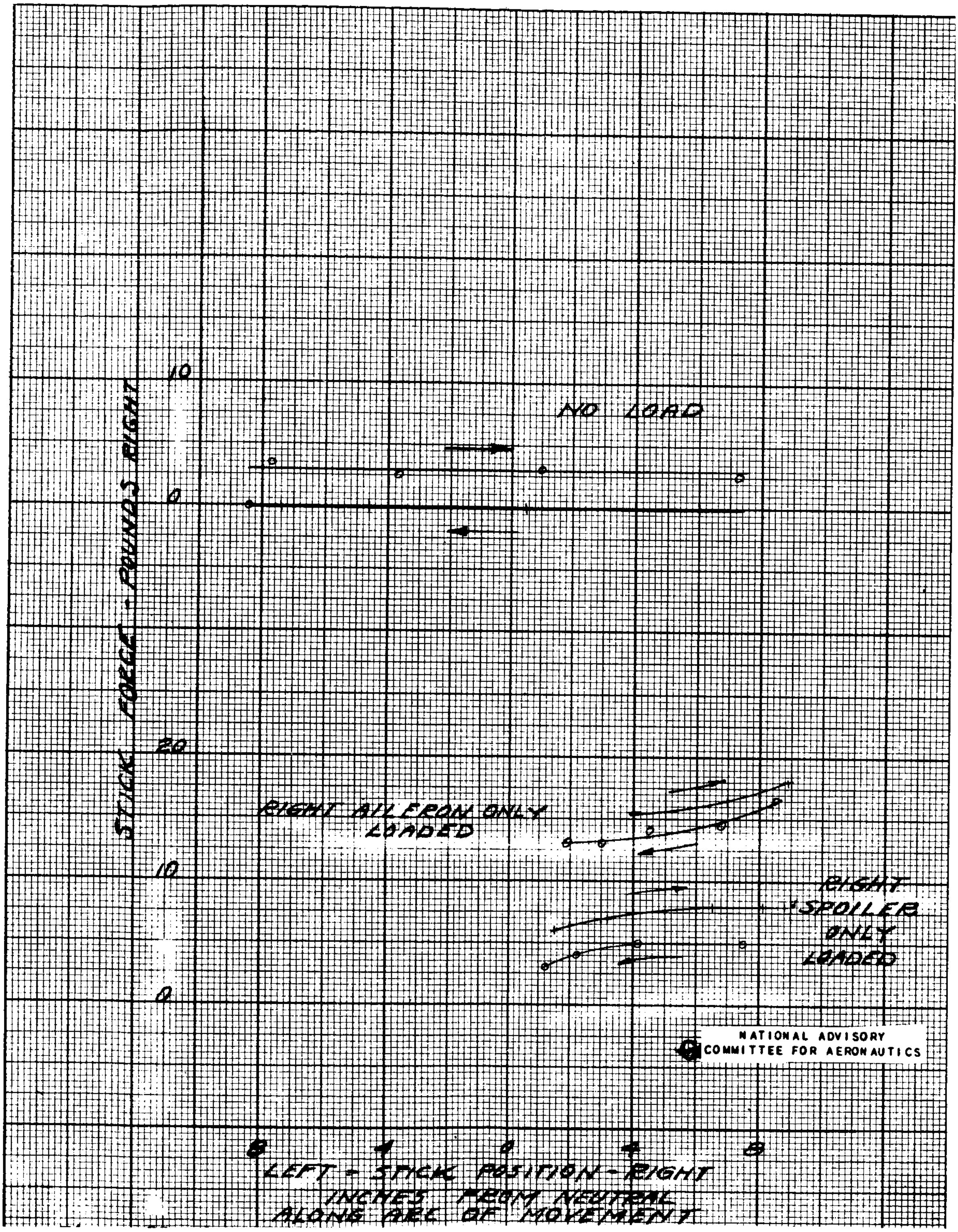


Figure 25.- Friction in the lateral control system, flaps 1/3 down, as indicated by the stick force required to move the controls on the ground.

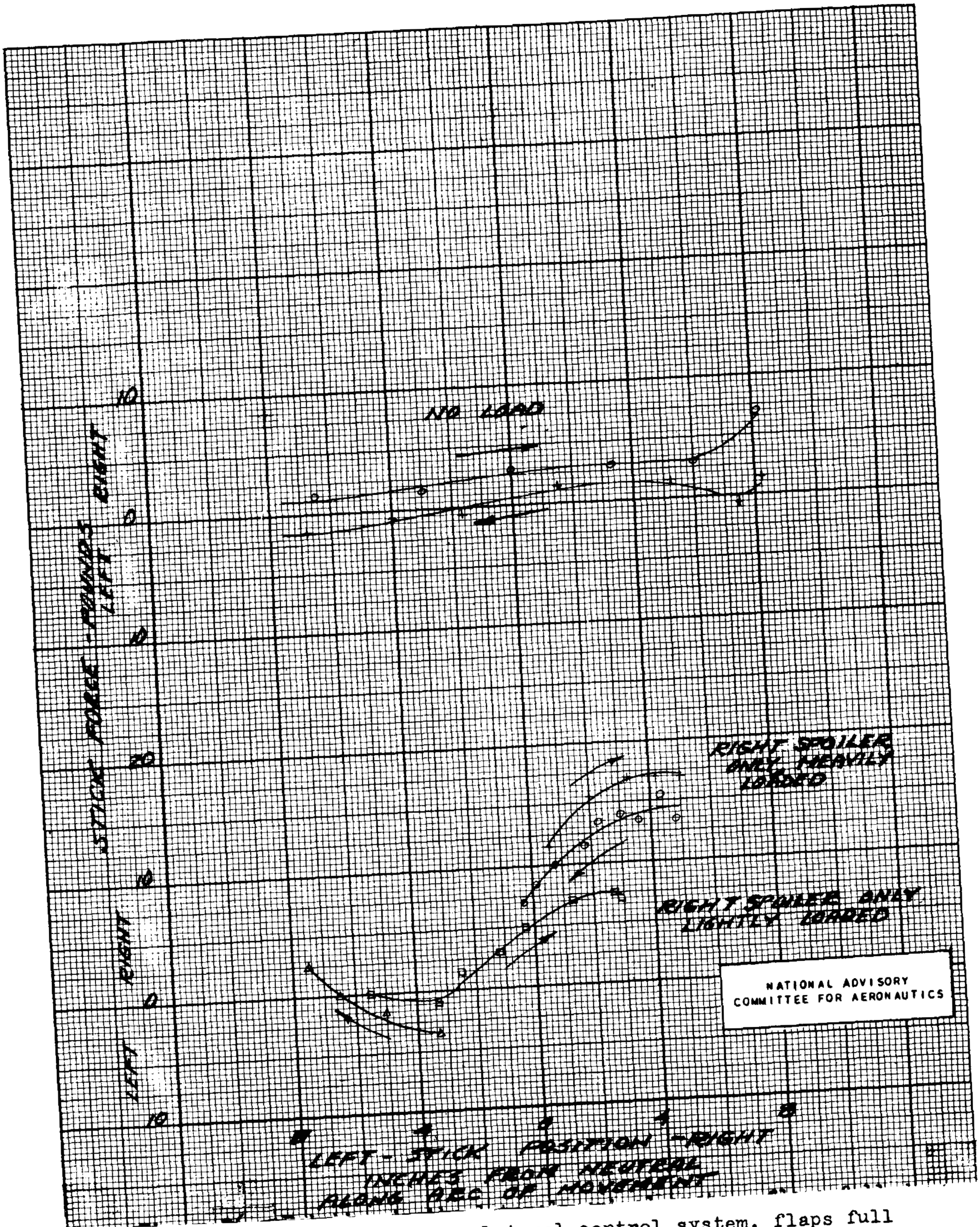


Figure 26.- Friction in the lateral control system, flaps full down, as indicated by the stick force required to move the controls on the ground.

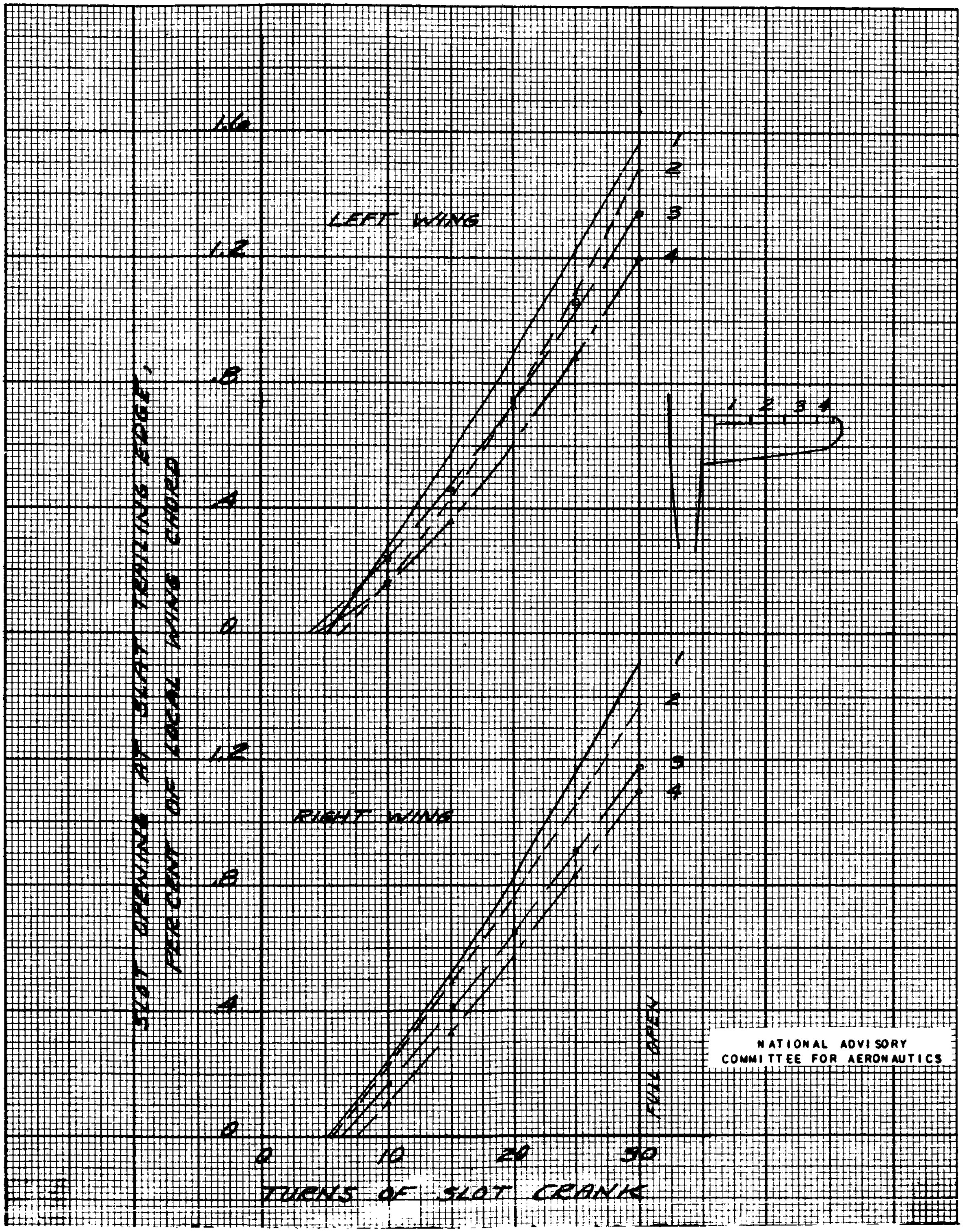


Figure 27.- Variation of slot opening with slot control crank position.

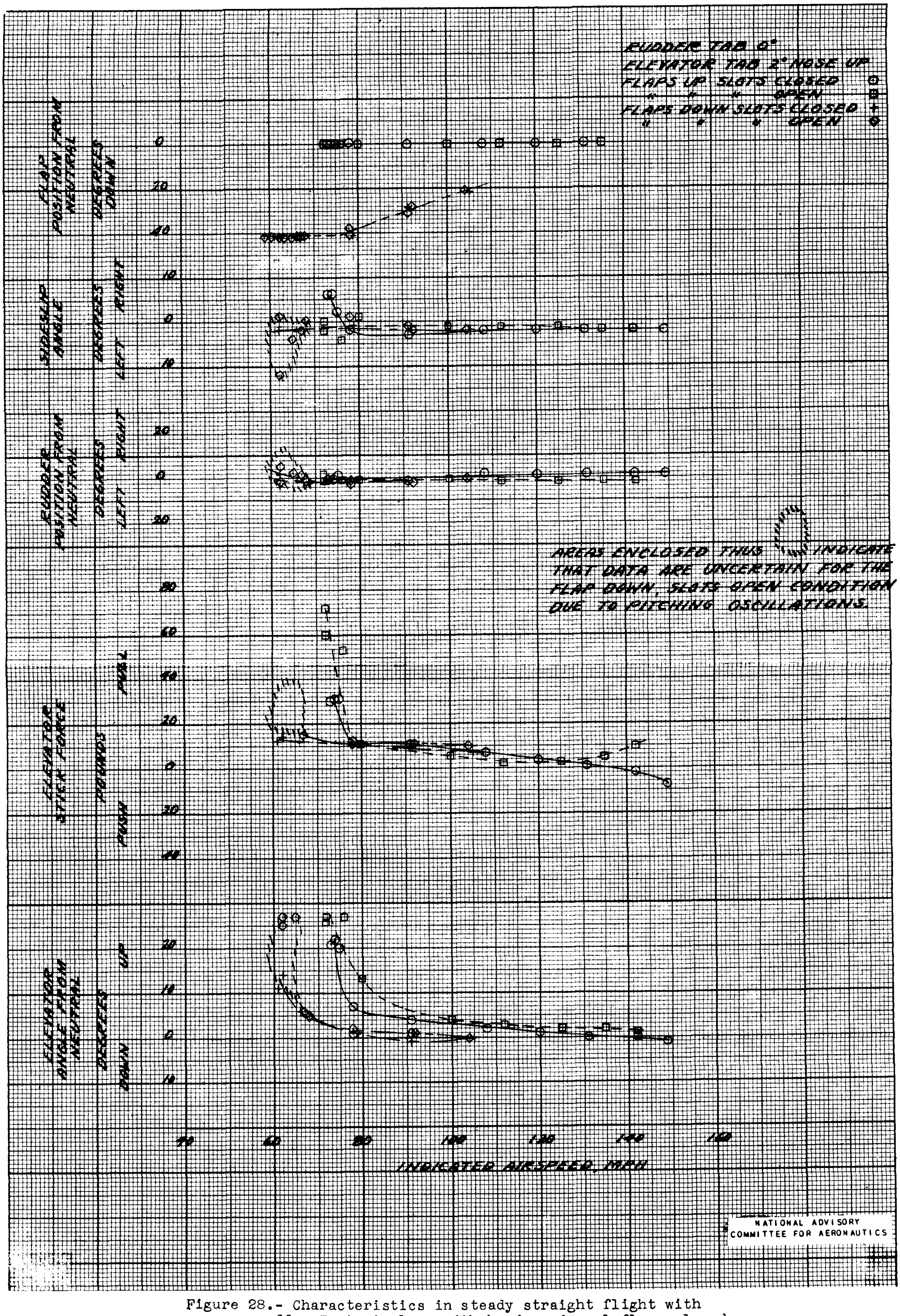


Figure 28.- Characteristics in steady straight flight with power off. Test airplane with hoods and cowl flaps closed, center of gravity at 26.3 percent M.A.C.

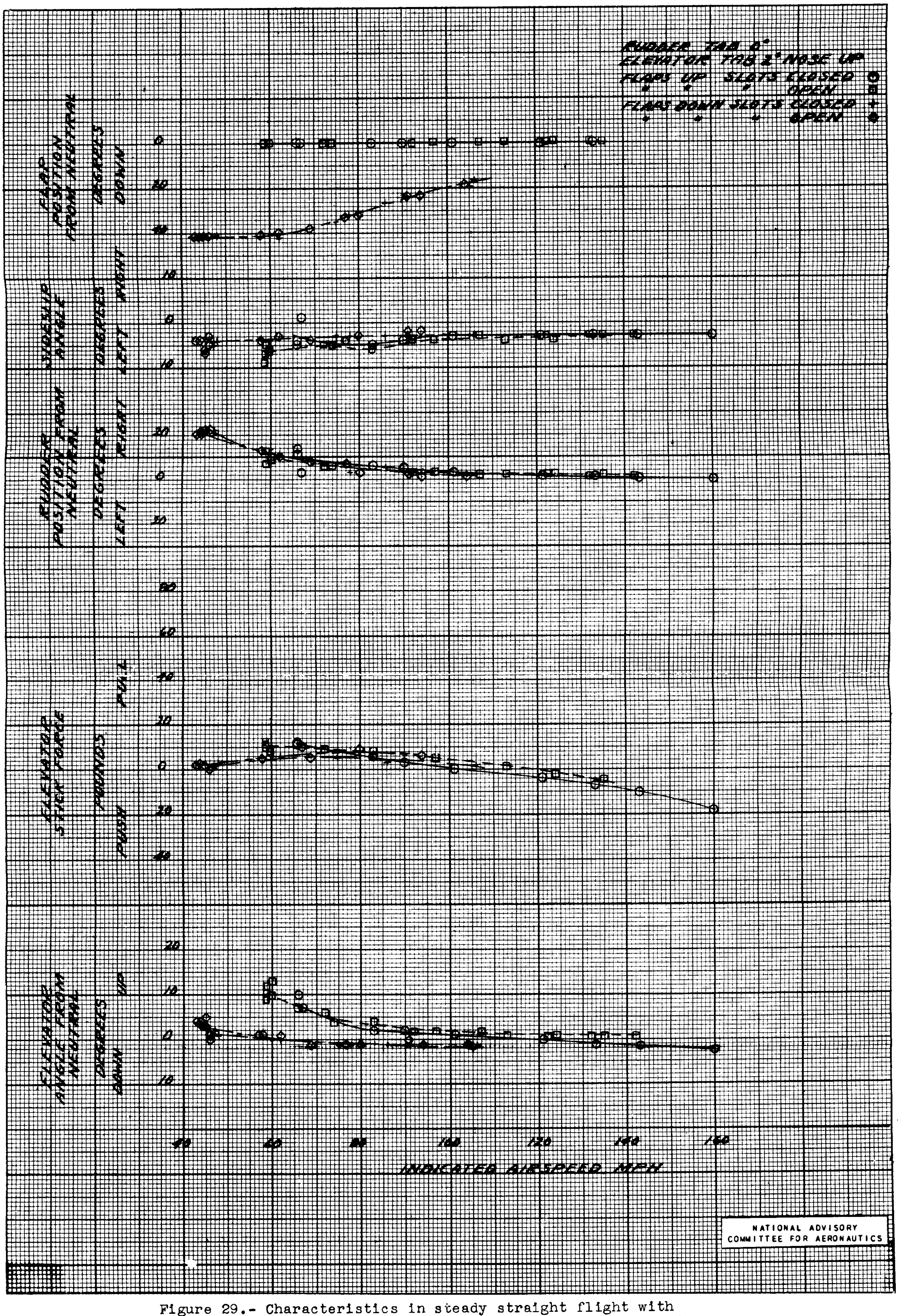


Figure 29.- Characteristics in steady straight flight with power for level flight. Test airplane with hoods closed, center of gravity at 26.3 percent M.A.C.

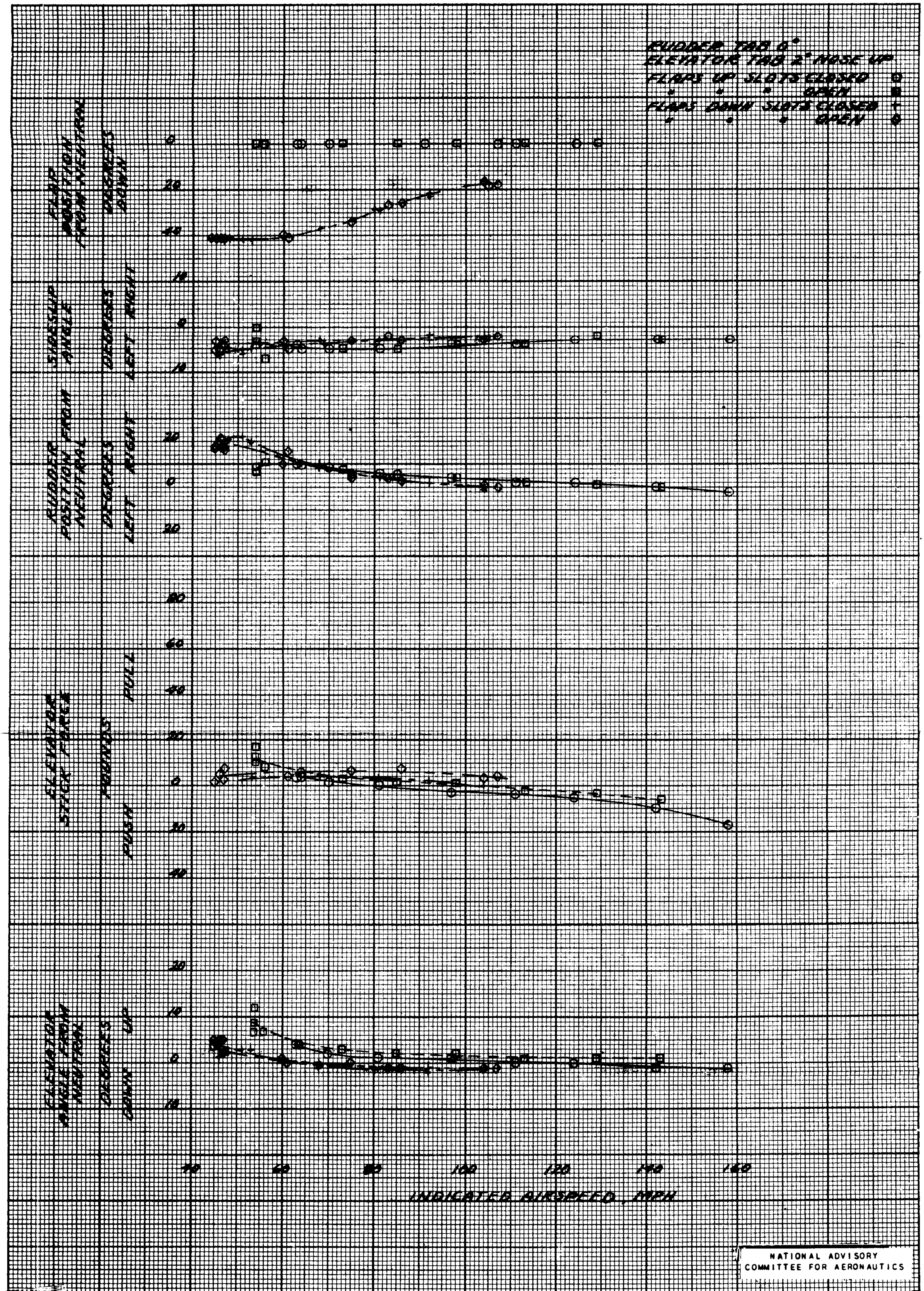


Figure 30.- Characteristics in steady straight flight with approximately 345 bhp at 2300 rpm. Test airplane with hoods closed and cowl flaps open, center of gravity at 26.3 percent M.A.C.

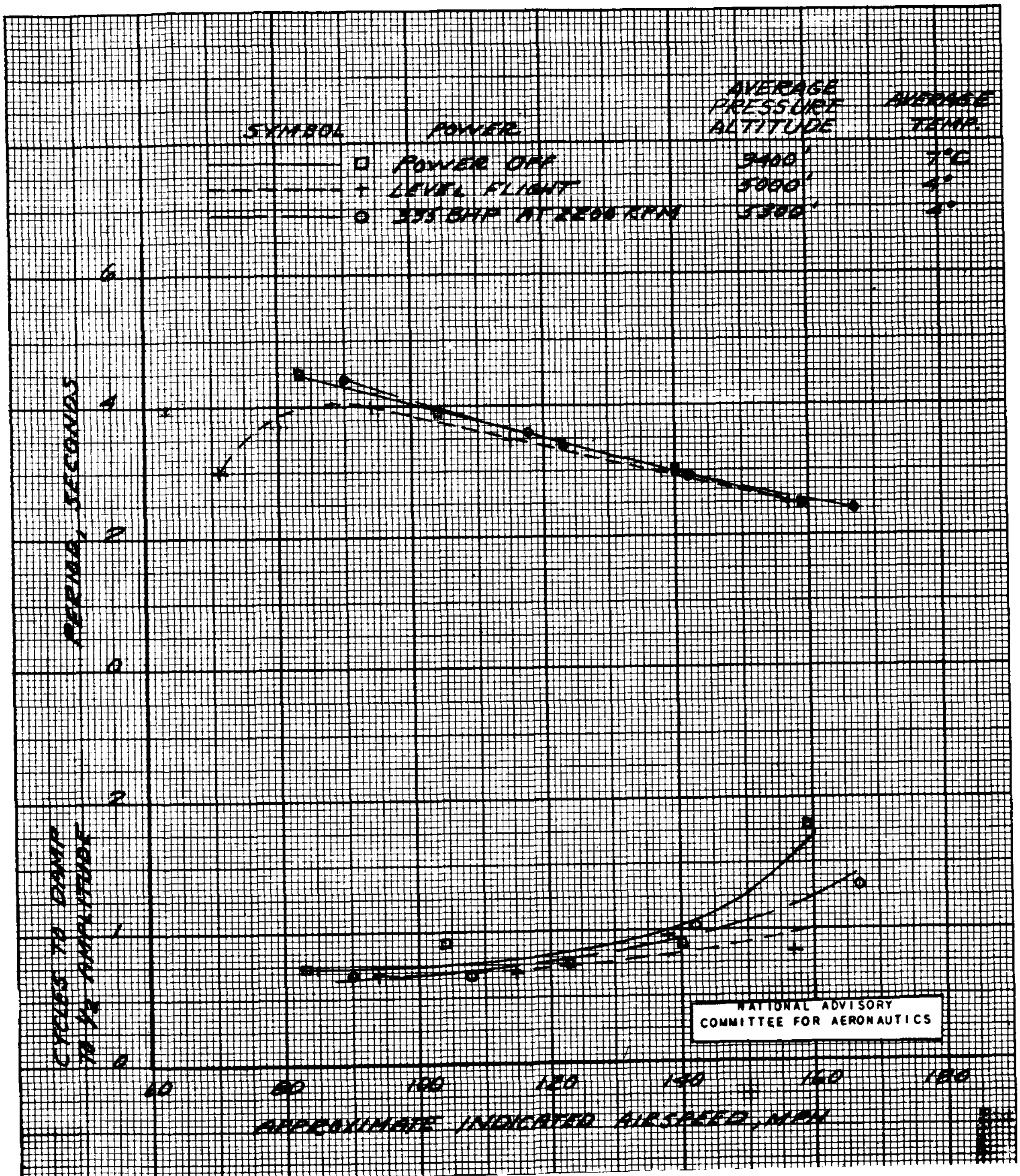


Figure 31.- Period and damping of the lateral oscillations. Test airplane with flaps up and slots closed, center of gravity at 26.3 percent M.A.C.

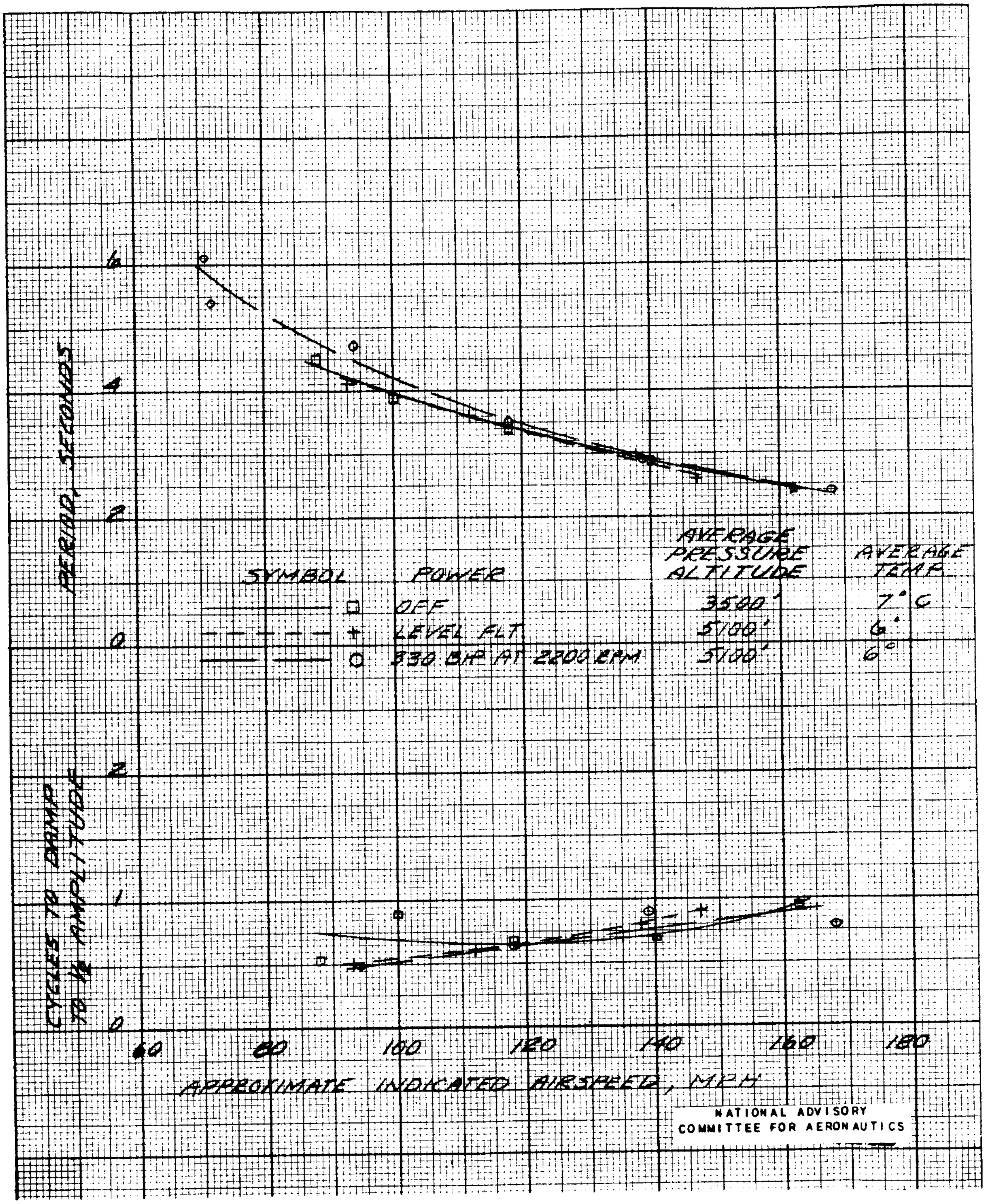


Figure 32.- Period and damping of the lateral oscillations. Test airplane with flaps up and slots open, center of gravity at 26.3 percent M.A.C.

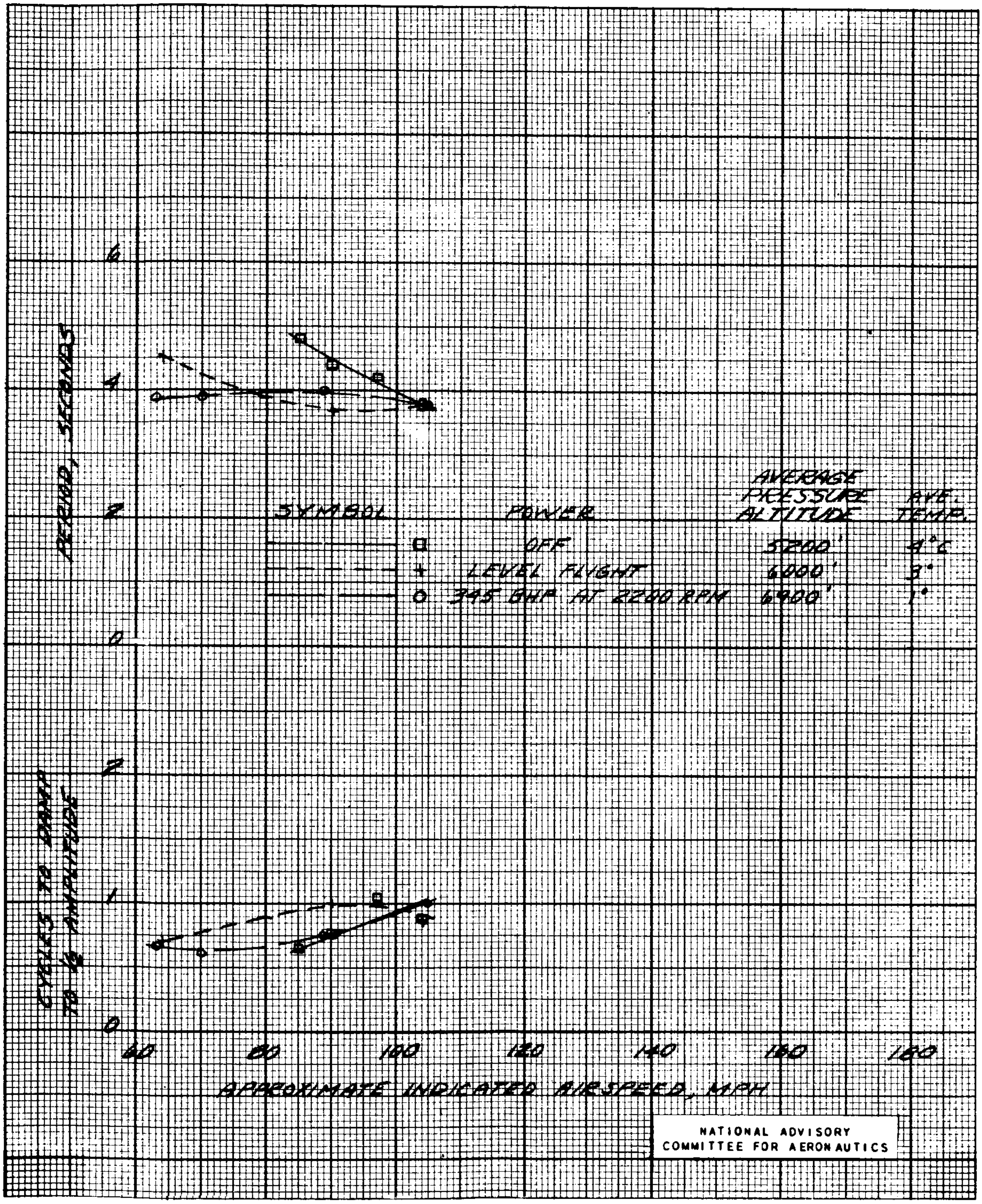


Figure 33.- Period and damping of the lateral oscillations. Test airplane with flaps set full down and slots closed, center of gravity at 26.3 percent M.A.C.

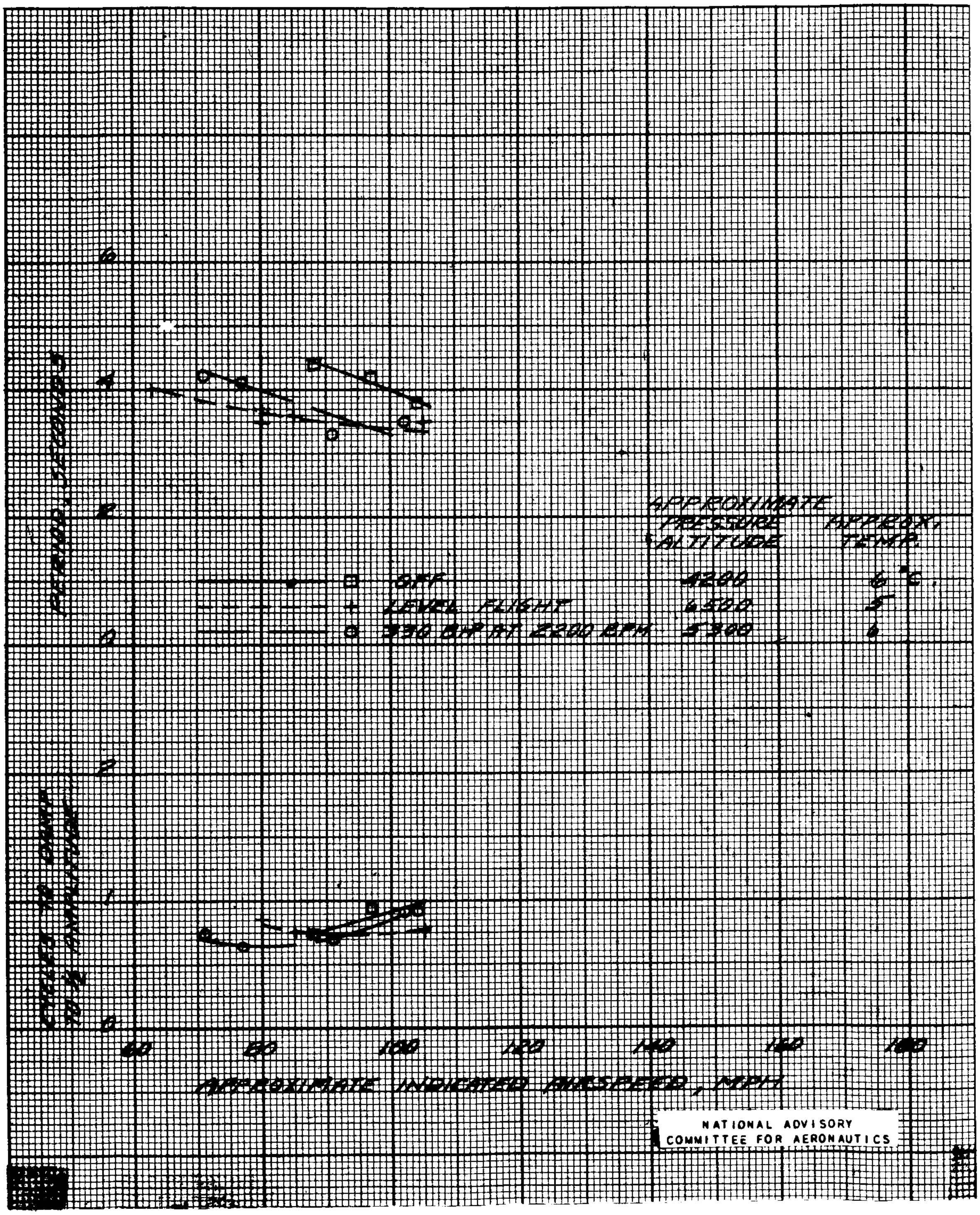


Figure 34.- Period and damping of the lateral oscillations. Test airplane with flaps set full down and slots open, center of gravity at 26.3 percent M.A.C.

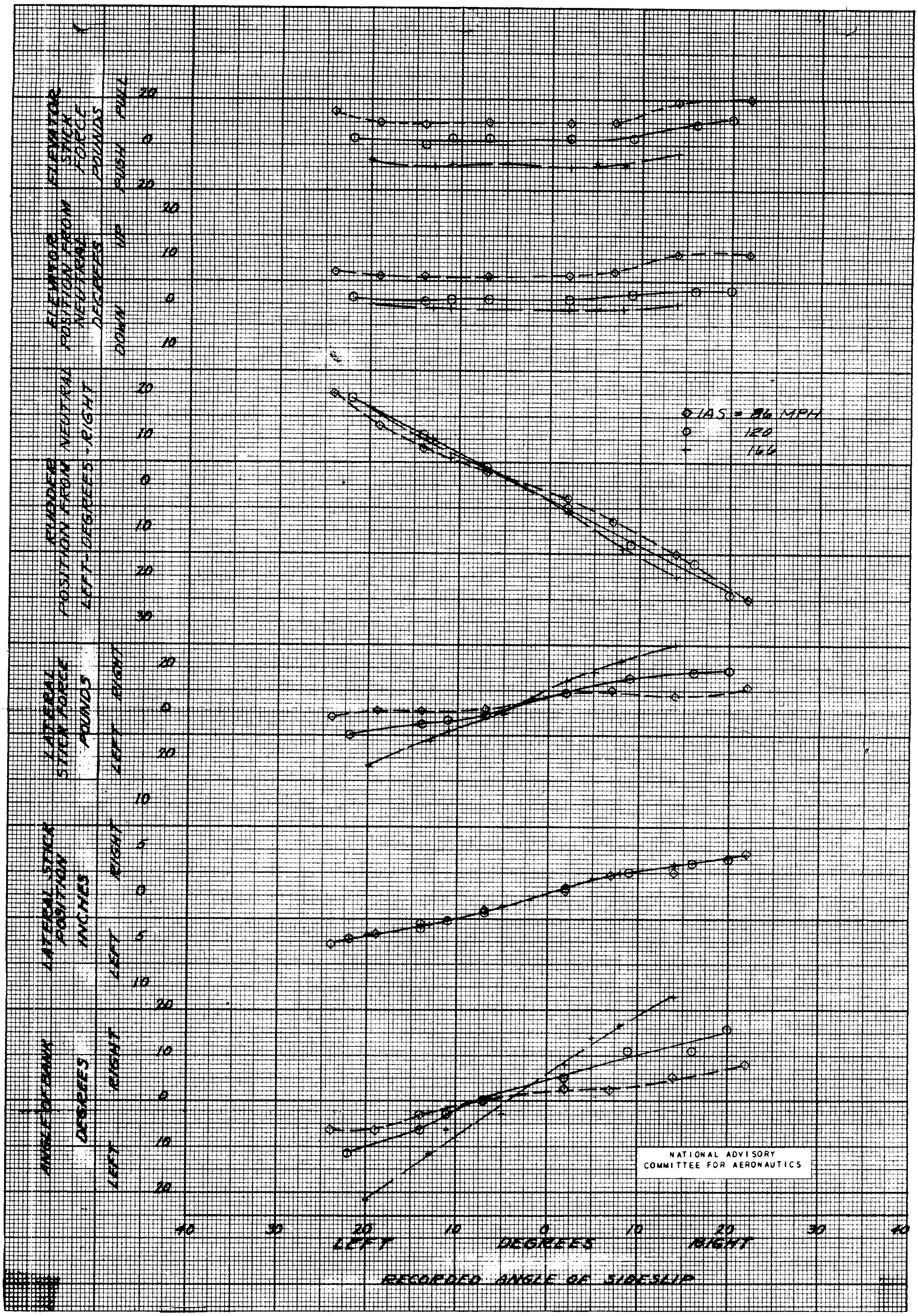


Figure 35.- Characteristics in steady sideslips. Power off, flaps up, slots, hoods, and cowl flaps closed, center of gravity at 26.3 percent M.A.C.

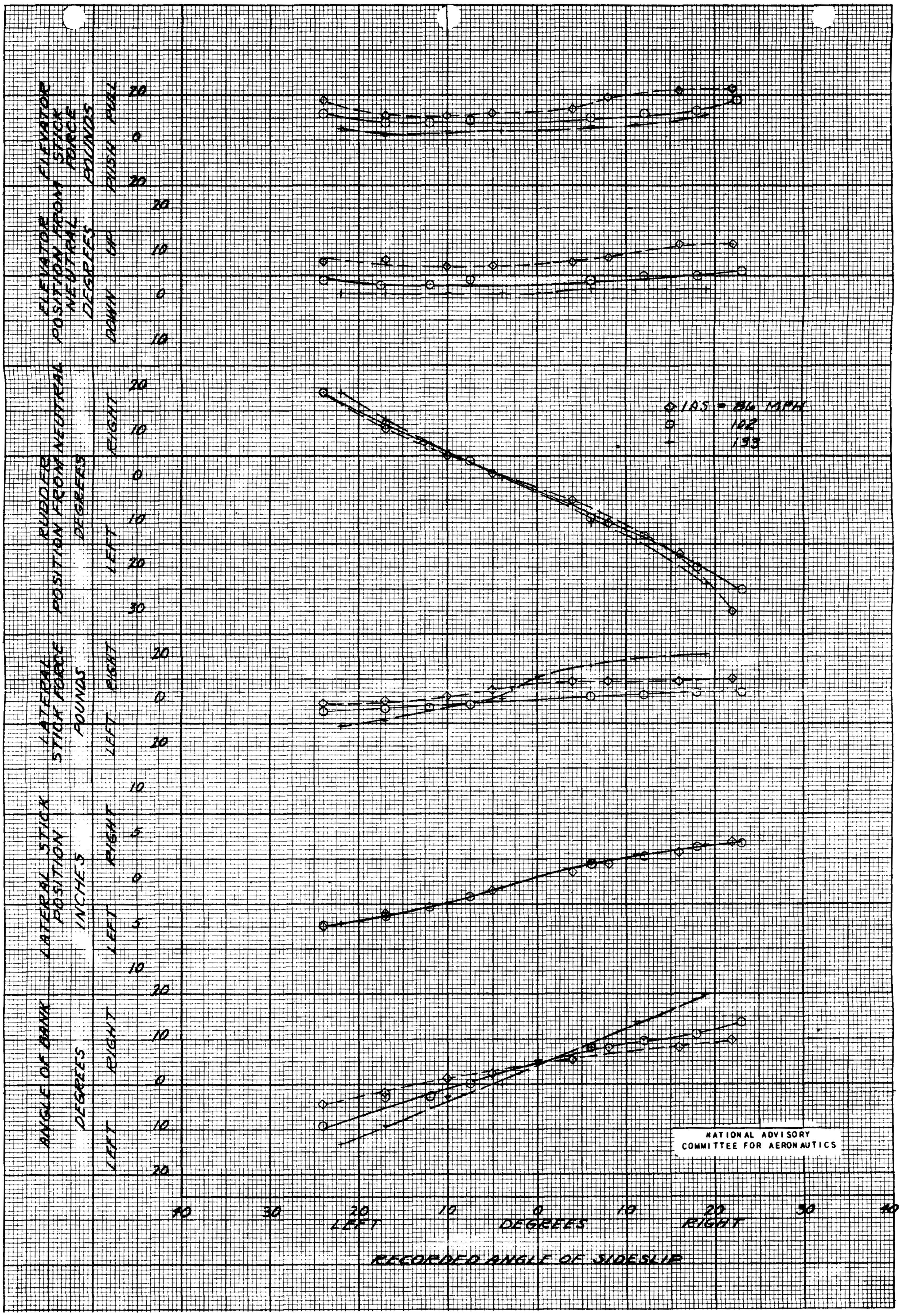


Figure 36.- Characteristics in steady sideslips. Power off, flaps up, slots open, hoods and cowl flaps closed, center of gravity at 26.3 percent M.A.C.

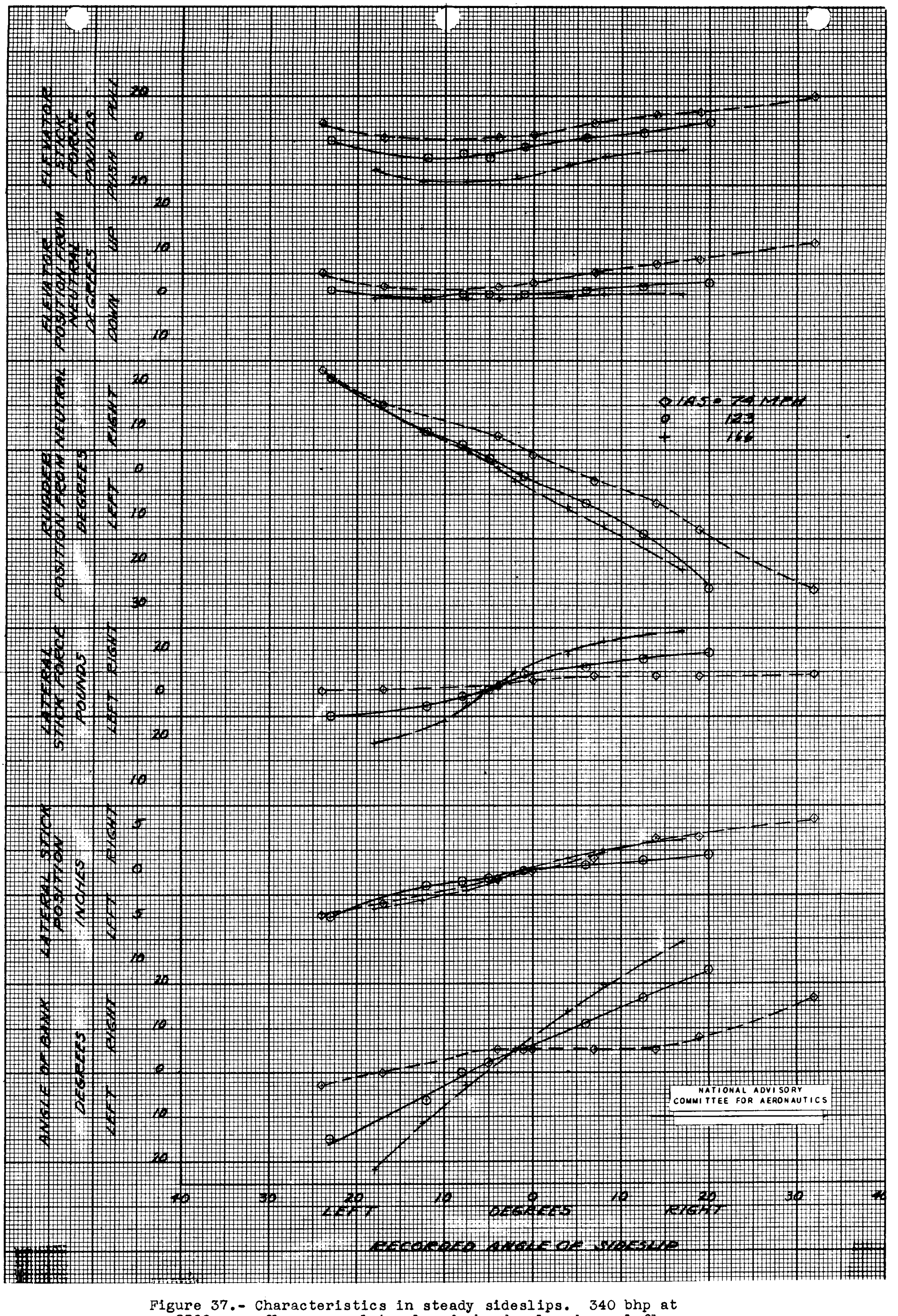


Figure 37.- Characteristics in steady sideslips. 340 bhp at 2300 rpm, flaps up, slots closed, hoods closed, cowl flaps open, center of gravity at 26.3 percent M.A.C.

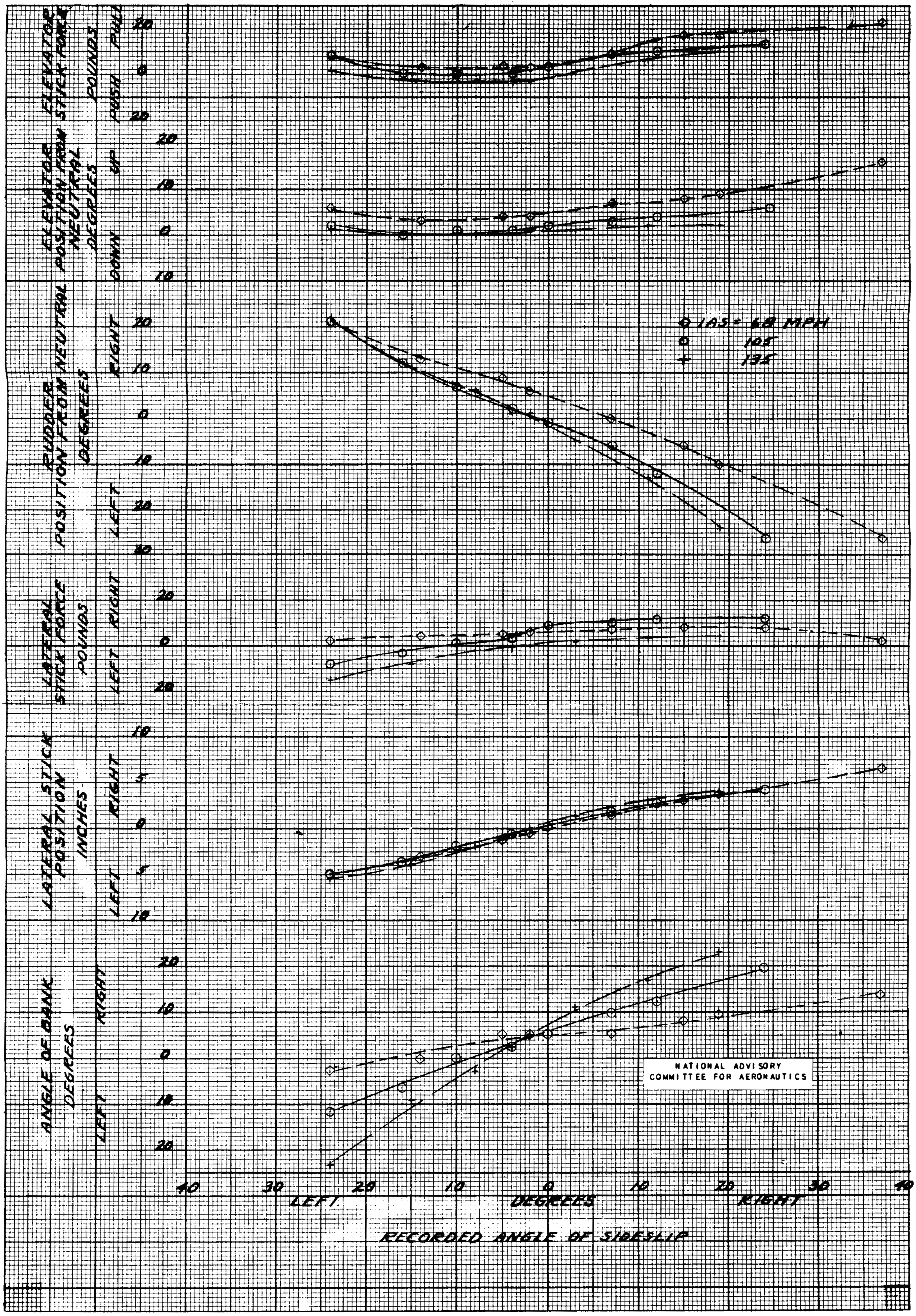


Figure 38.- Characteristics in steady sideslips. 340 bhp at 2300 rpm, flaps up, slots open, hoods closed, cowl flaps open, center of gravity at 26.3 percent M.A.C.

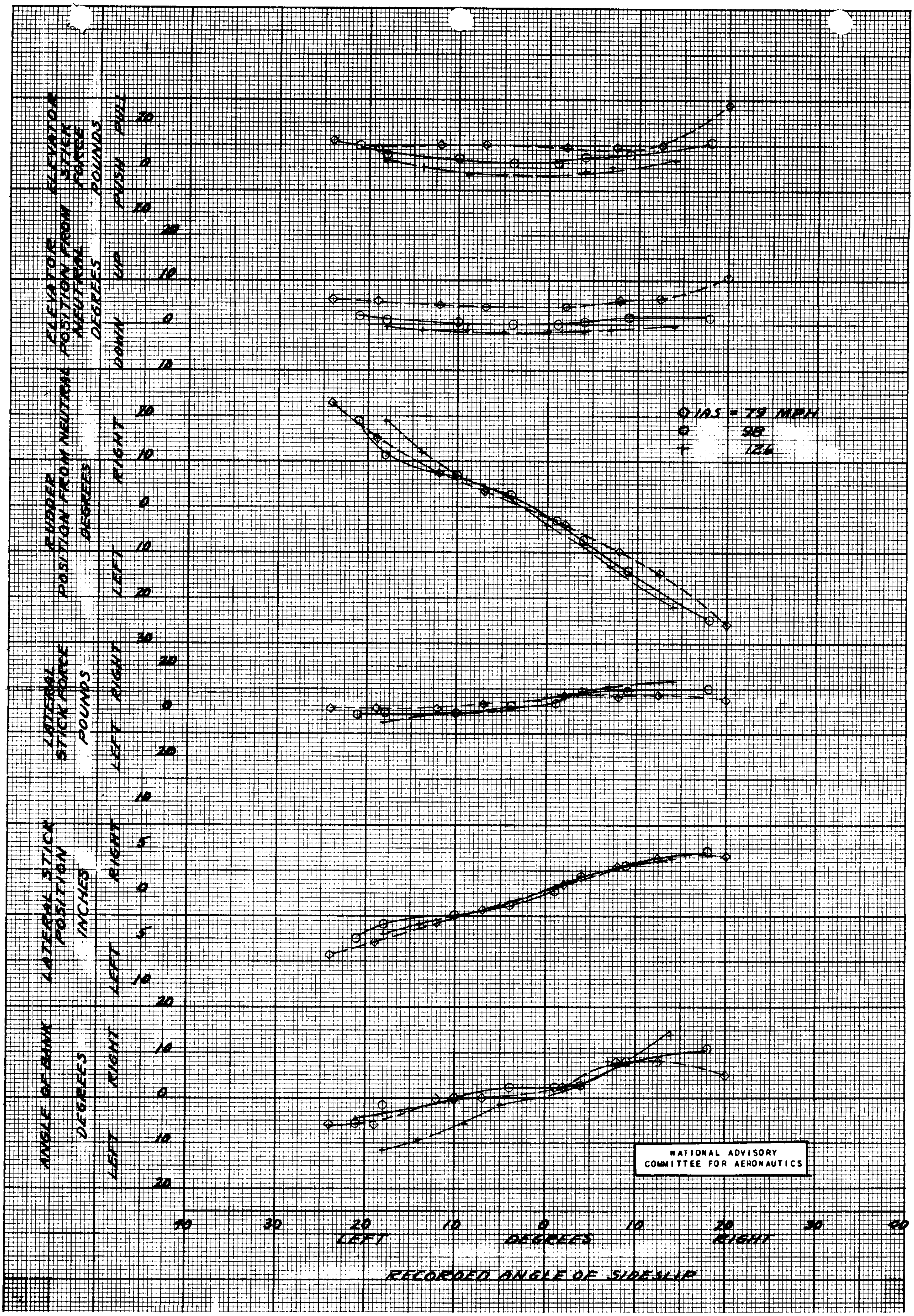


Figure 39.- Characteristics in steady sideslips. Power off, flaps set 1/3 down, slots closed, hoods closed, cowl flaps closed, center of gravity at 26.3 percent M.A.C.

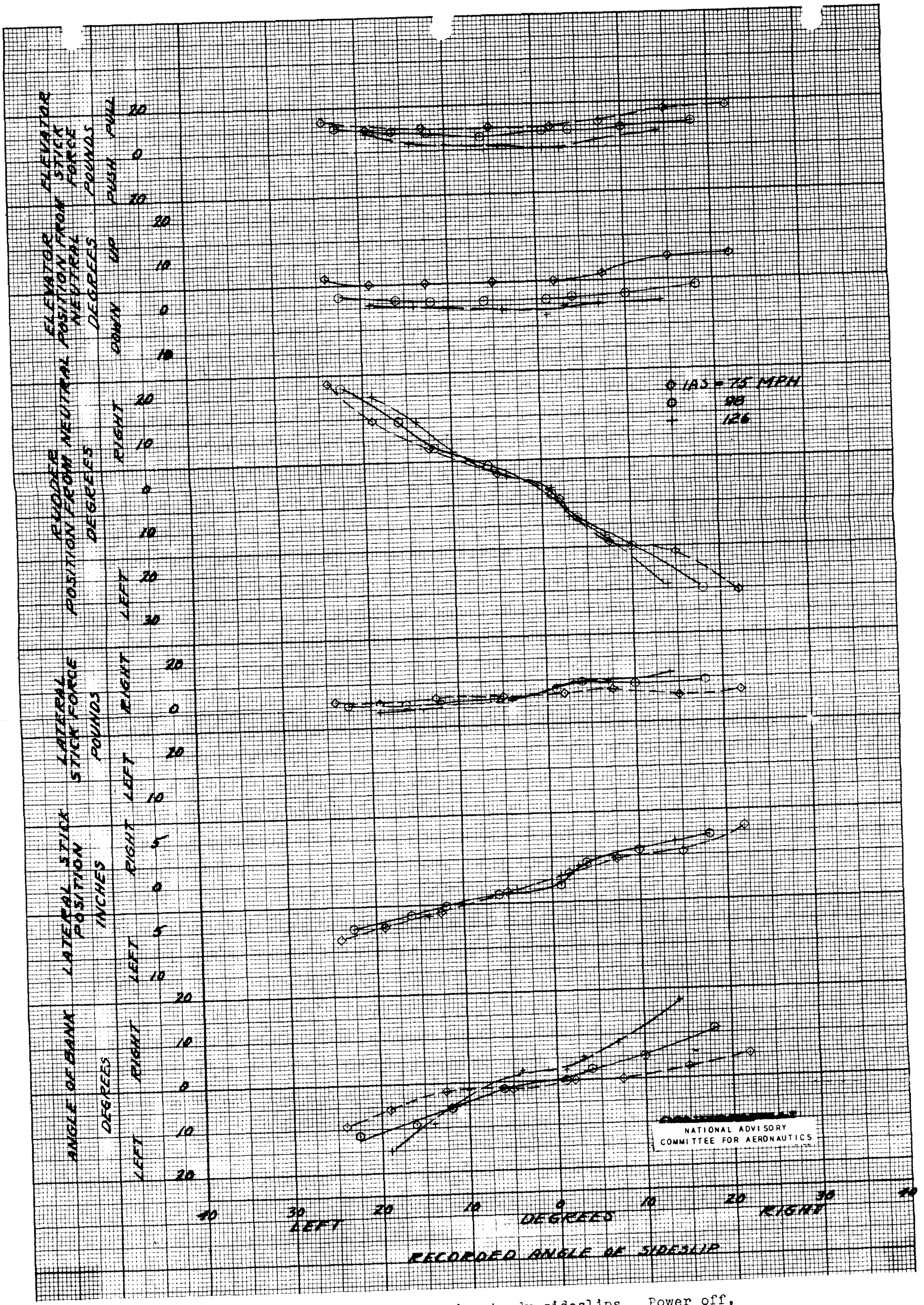


Figure 40.- Characteristics in steady sideslips. Power off, flaps set 1/3 down, slots open, hoods closed, cowl flaps closed, center of gravity at 26.3 percent M.A.C.

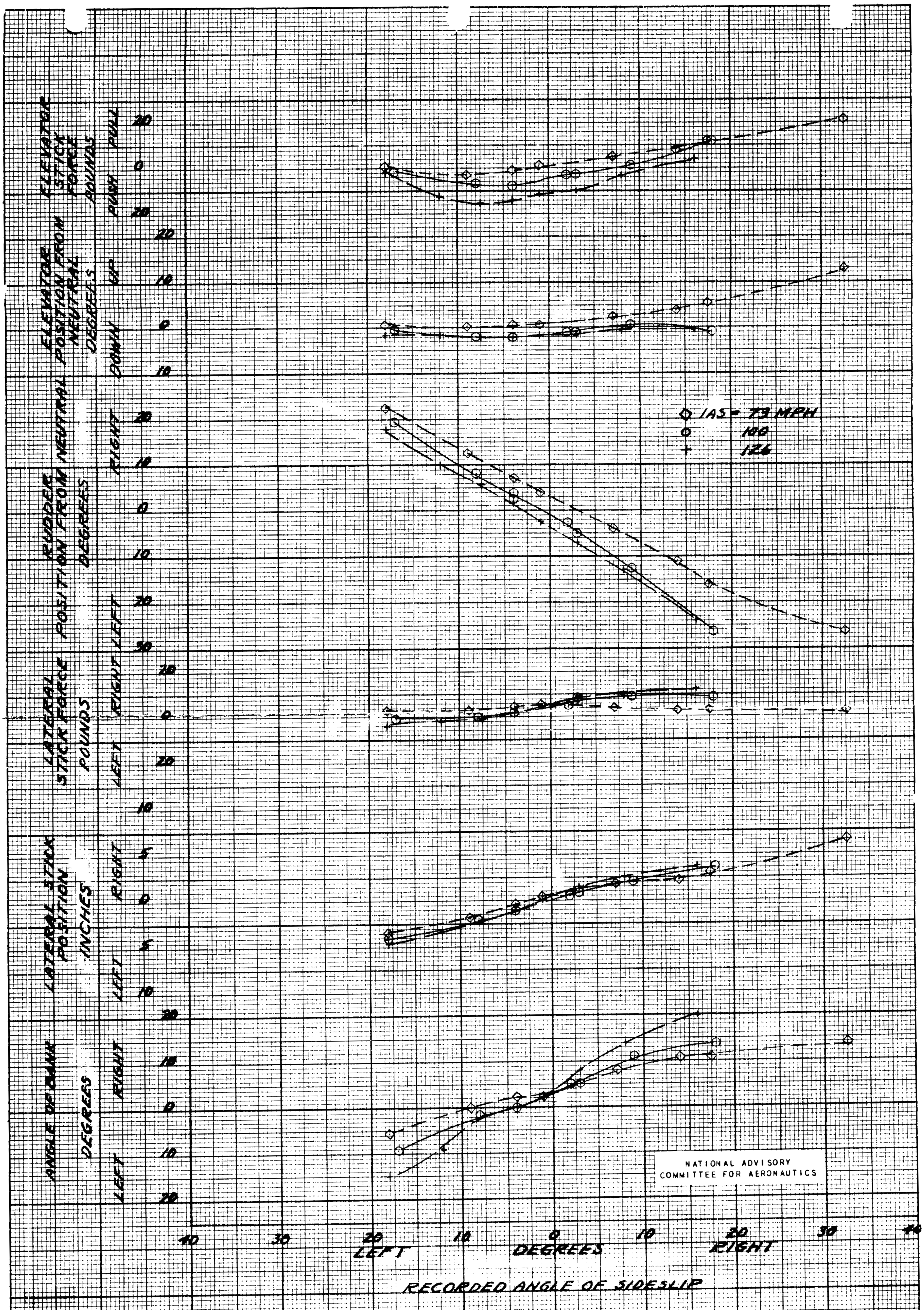


Figure 41.- Characteristics in steady sideslips. 340 bhp at 2300 rpm, flaps set 1/3 down, slots closed, hoods closed, cowl flaps open, center of gravity at 26.3 percent M.A.C.

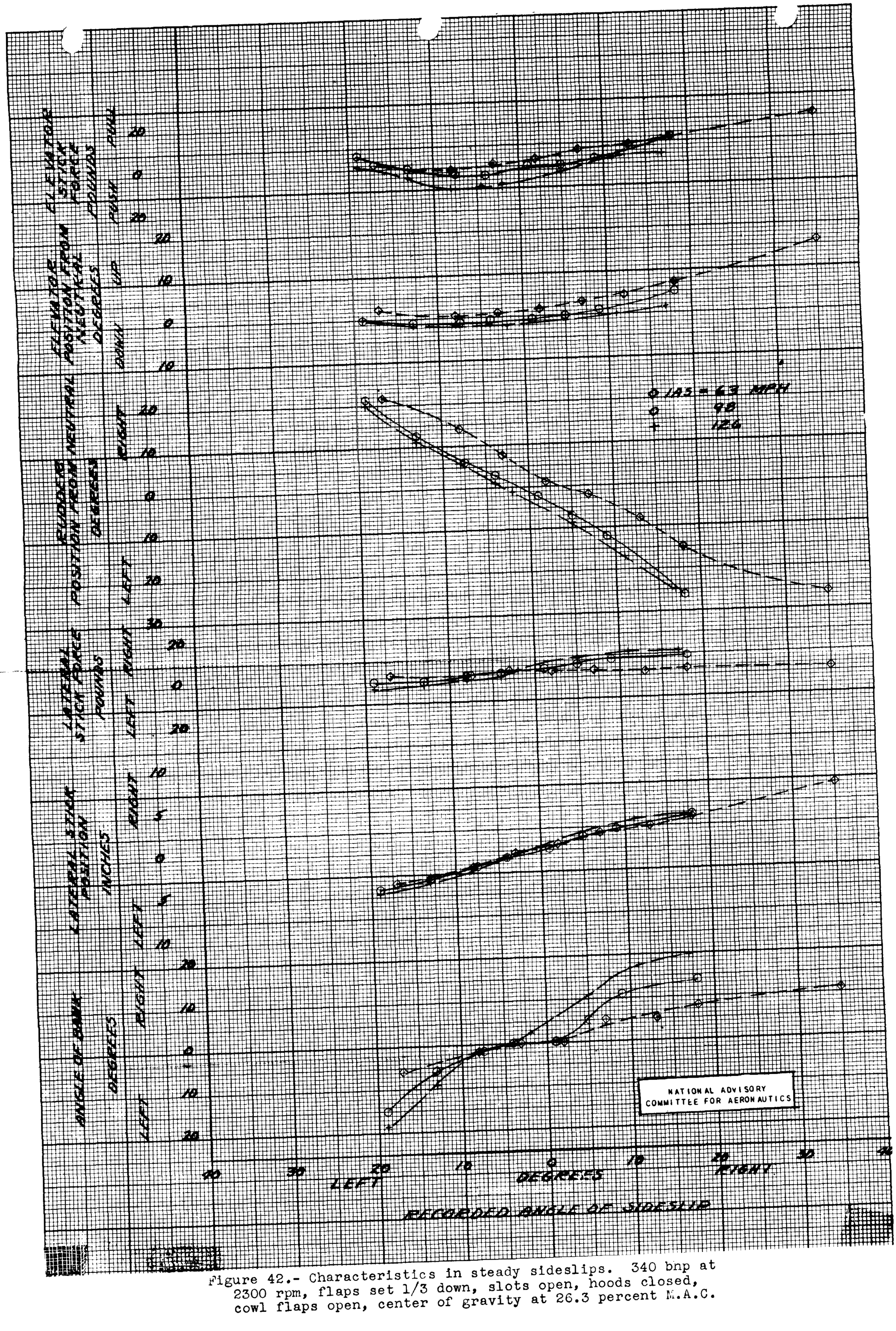


Figure 42.- Characteristics in steady sideslips. 340 bhp at 2300 rpm, flaps set 1/3 down, slots open, hoods closed, cowl flaps open, center of gravity at 26.3 percent M.A.C.

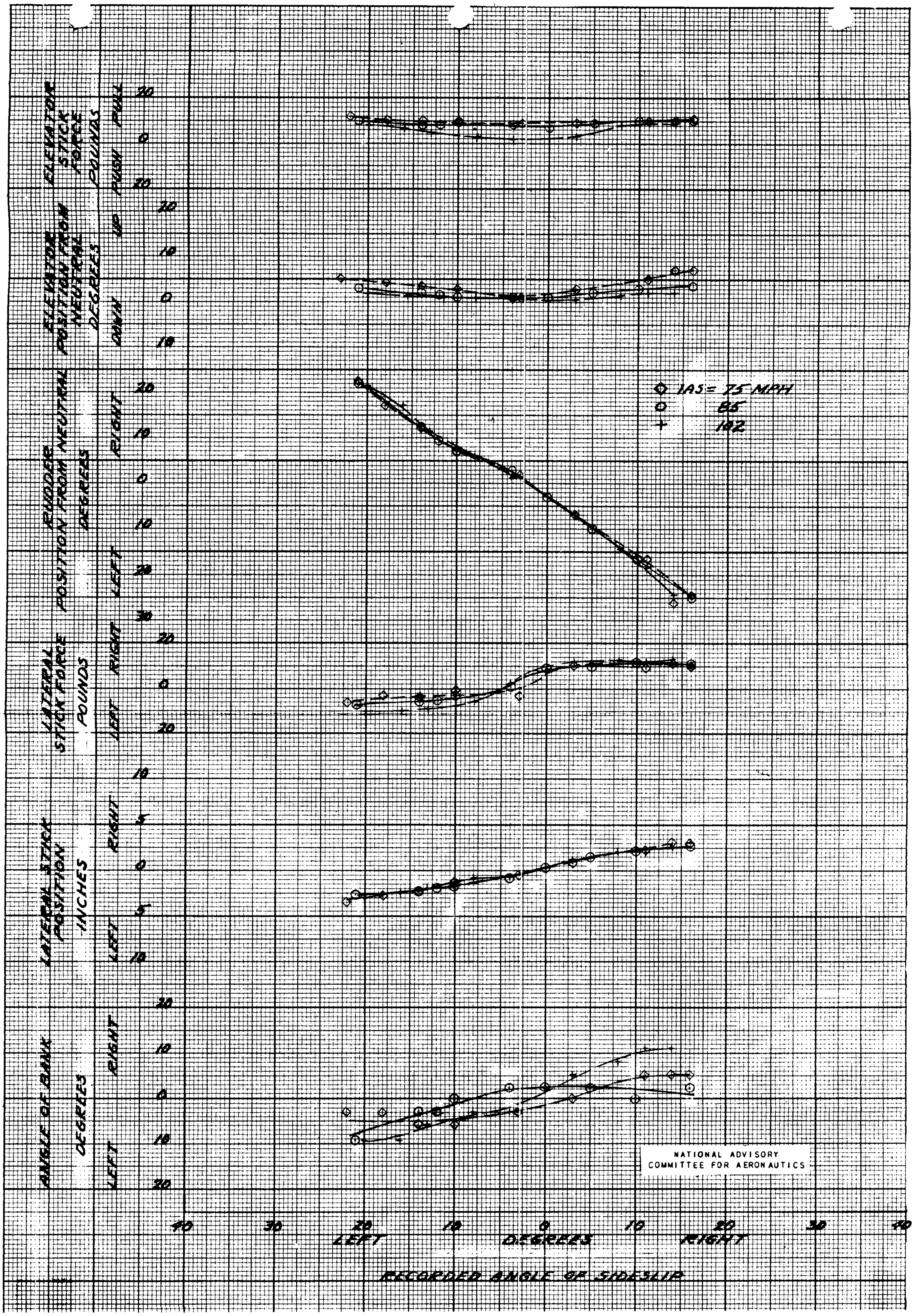


Figure 43.- Characteristics in steady sideslips. Power off, flaps set full down, slots closed, hoods closed, cowl flaps closed, center of gravity at 26.3 percent M.A.C.

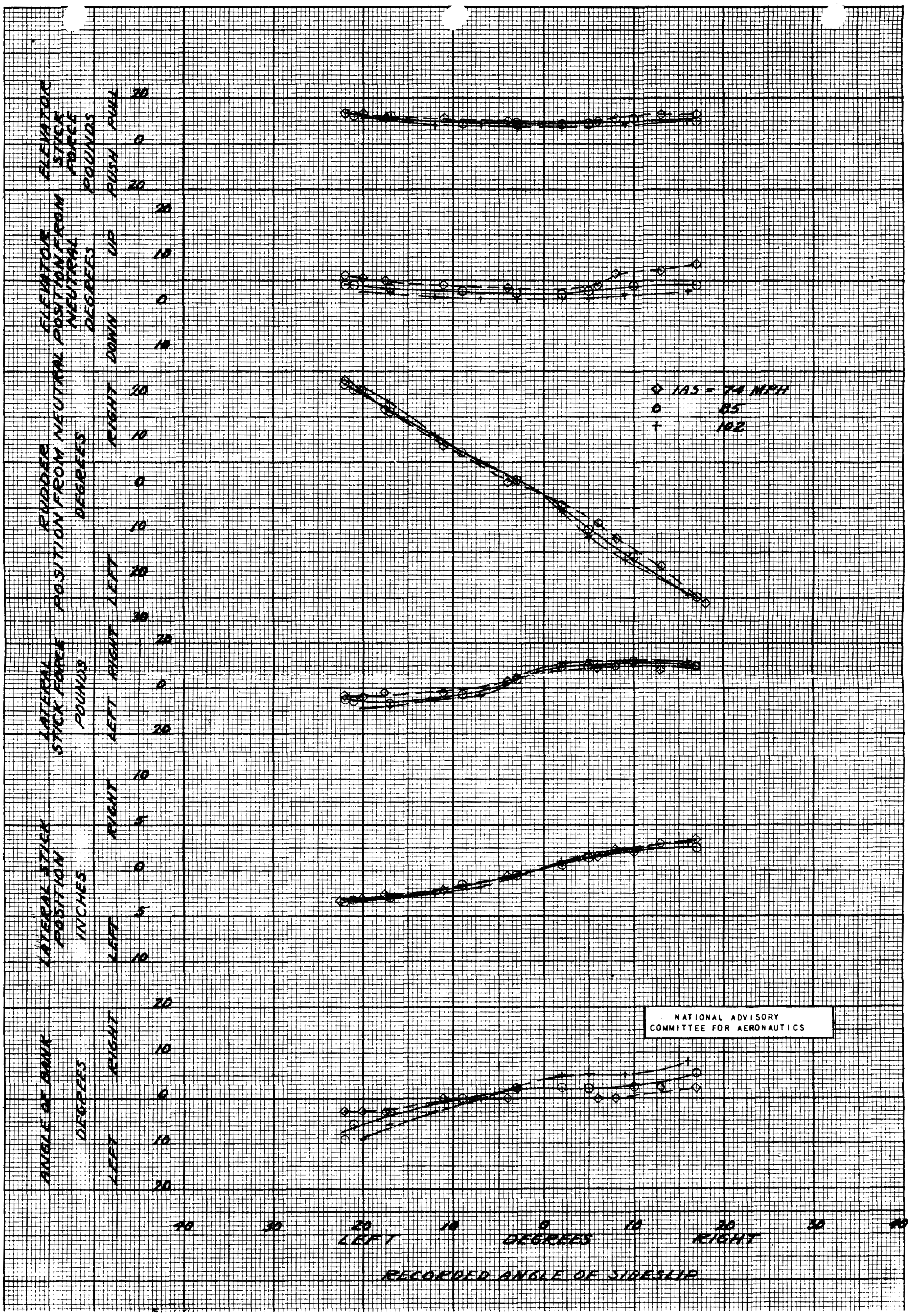


Figure 44.- Characteristics in steady sideslips. Power off, flaps set full down, slots open, hoods closed, cowl flaps closed, center of gravity at 26.3 percent M.A.C.

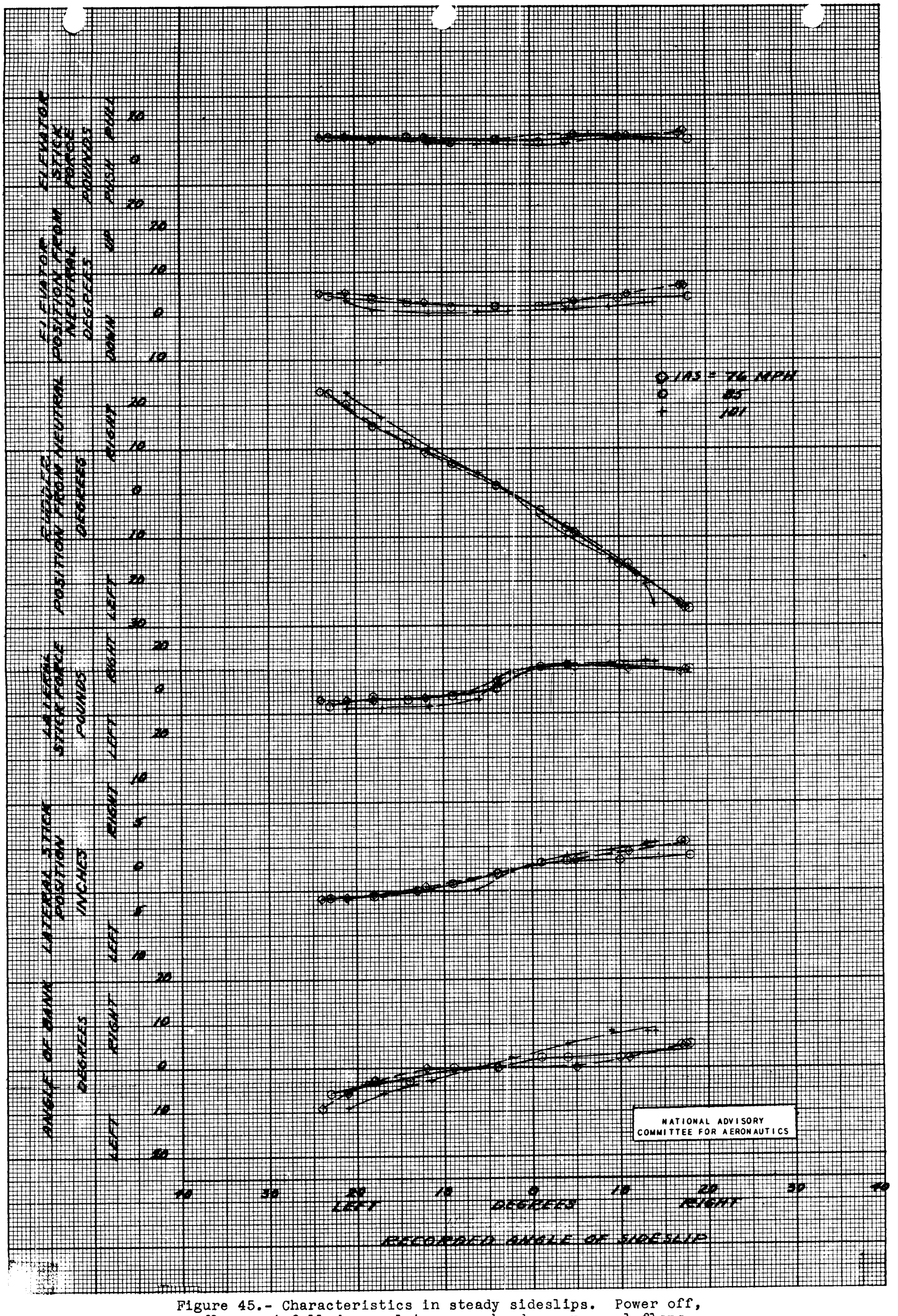


Figure 45.- Characteristics in steady sideslips. Power off, flaps set full down, slots open, hoods open, cowl flaps closed, center of gravity at 26.3 percent M.A.C.

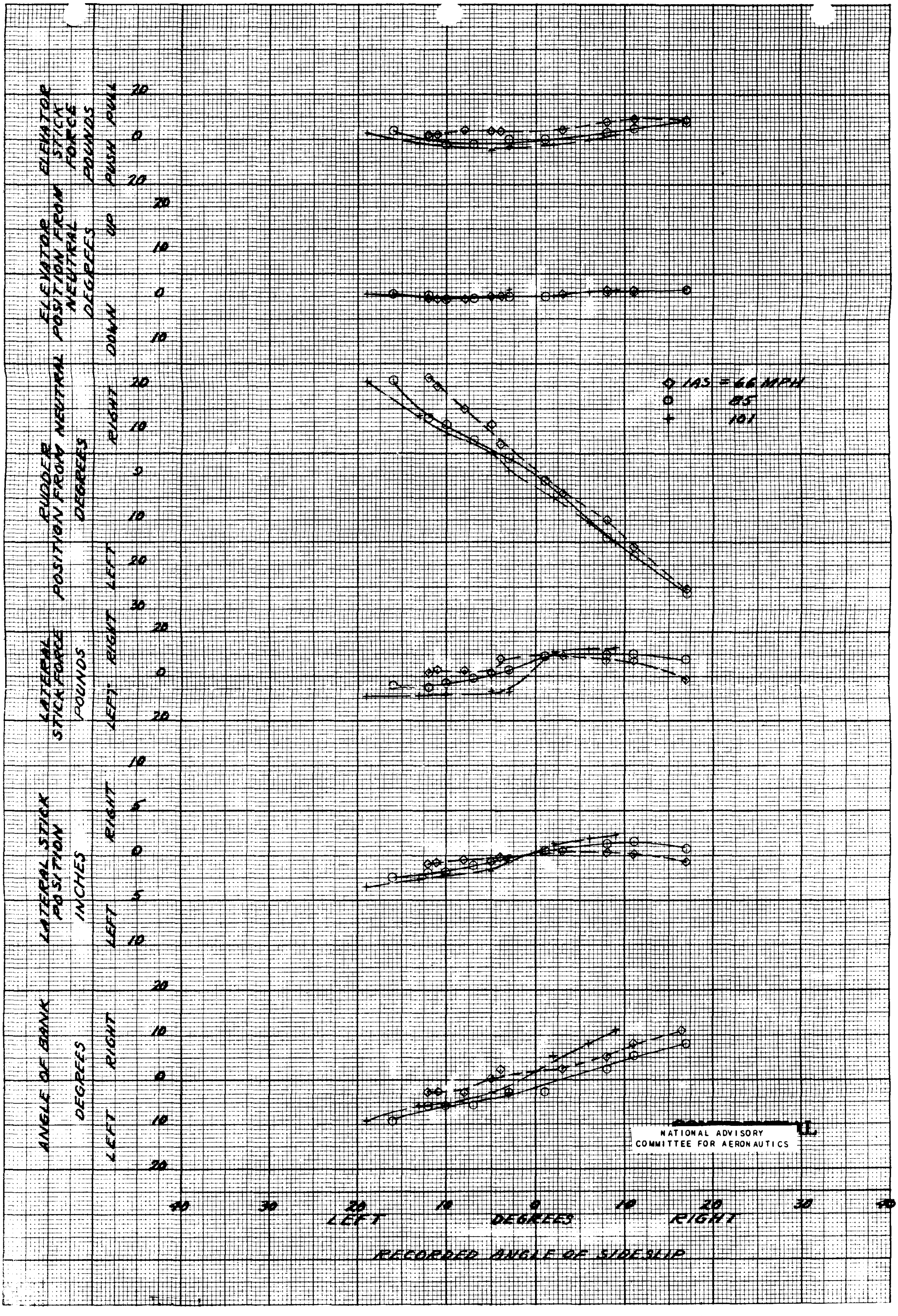


Figure 46.- Characteristics in steady sideslips. 340 bhp at 2300 rpm, flap set full down, slots closed, hoods closed, cowl flaps open, center of gravity at 26.3 percent M.A.C.

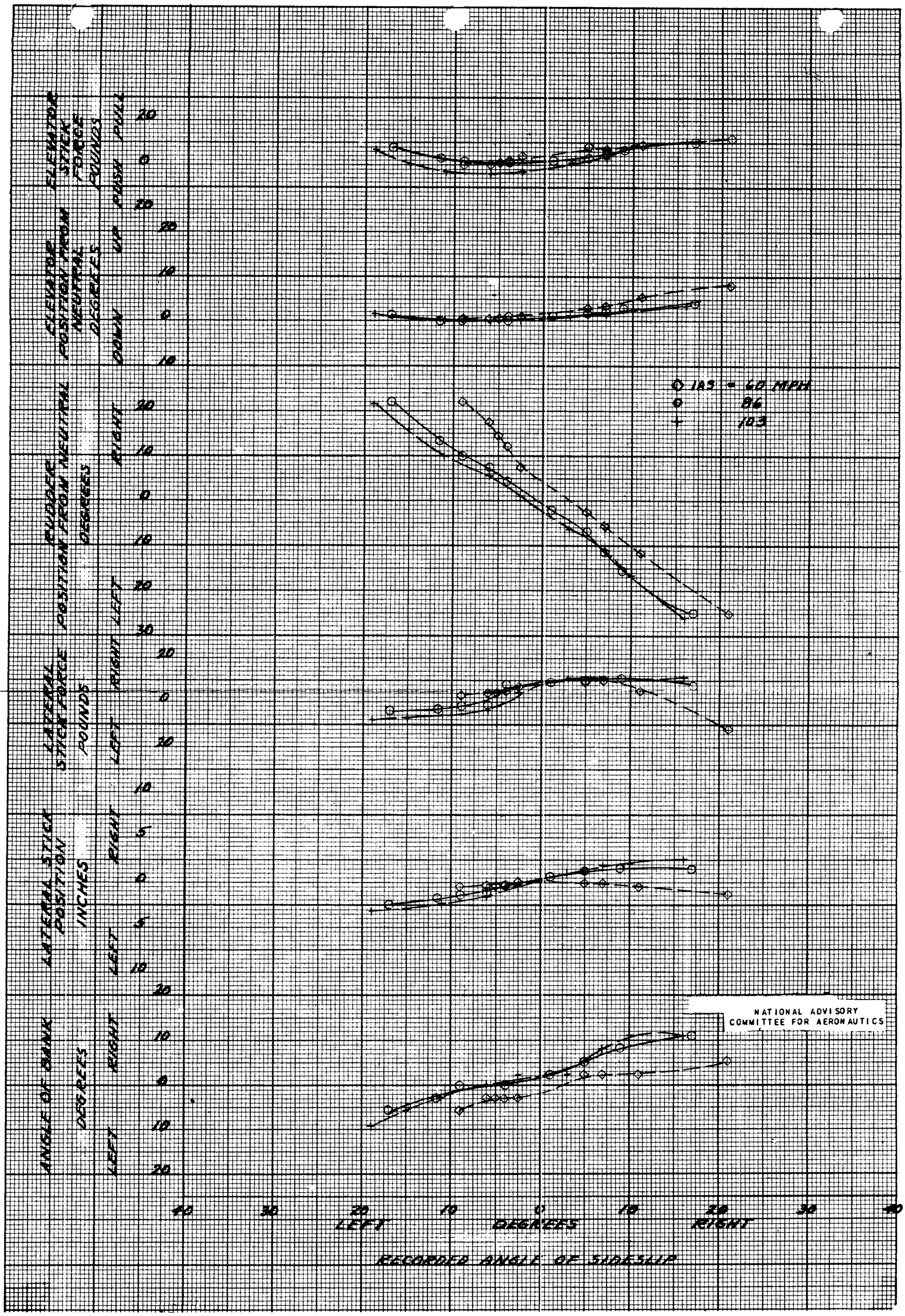


Figure 47.- Characteristics in steady sideslips. 340 bhp at 2300 rpm, flap set full down, slots open, hoods closed, cowl flaps open, center of gravity at 26.3 percent M.A.C.

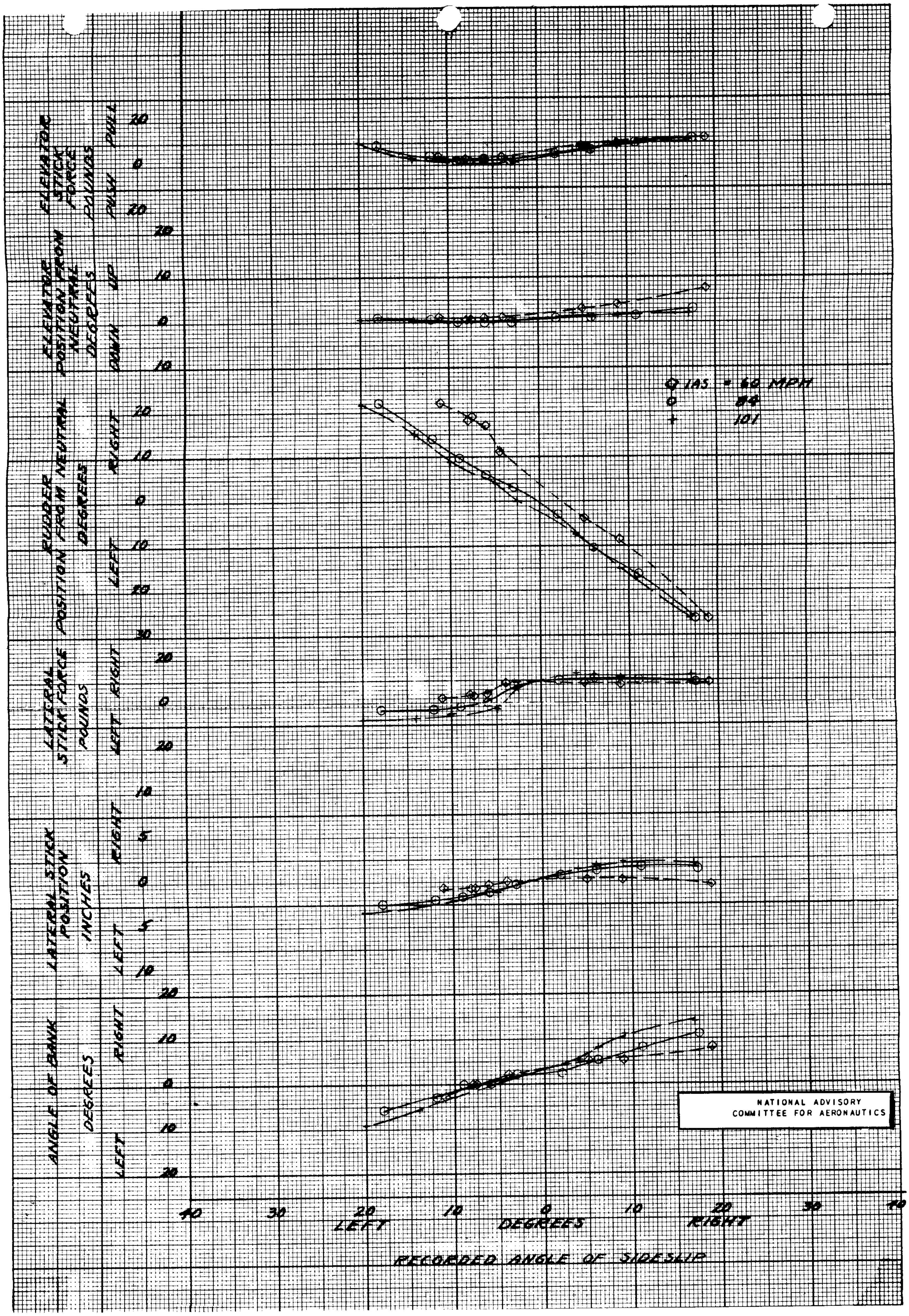


Figure 48.- Characteristics in steady sideslips. 340 bhp at 2300 rpm, flap set full down, slots open, hoods open, cowl flaps open, center of gravity at 26.3 percent M.A.C.

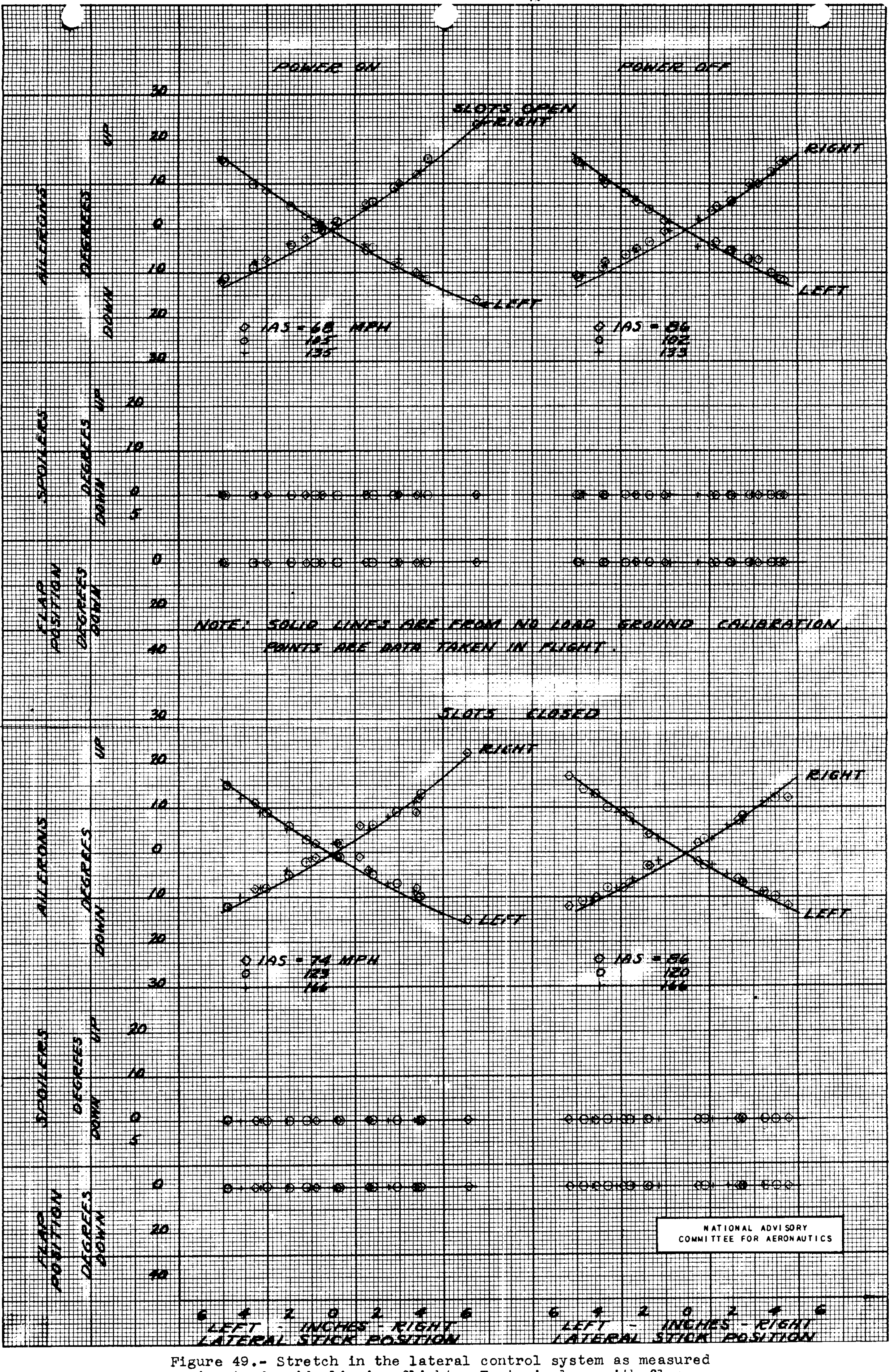


Figure 49.- Stretch in the lateral control system as measured in steady sideslipping flight. Test airplane with flaps up.

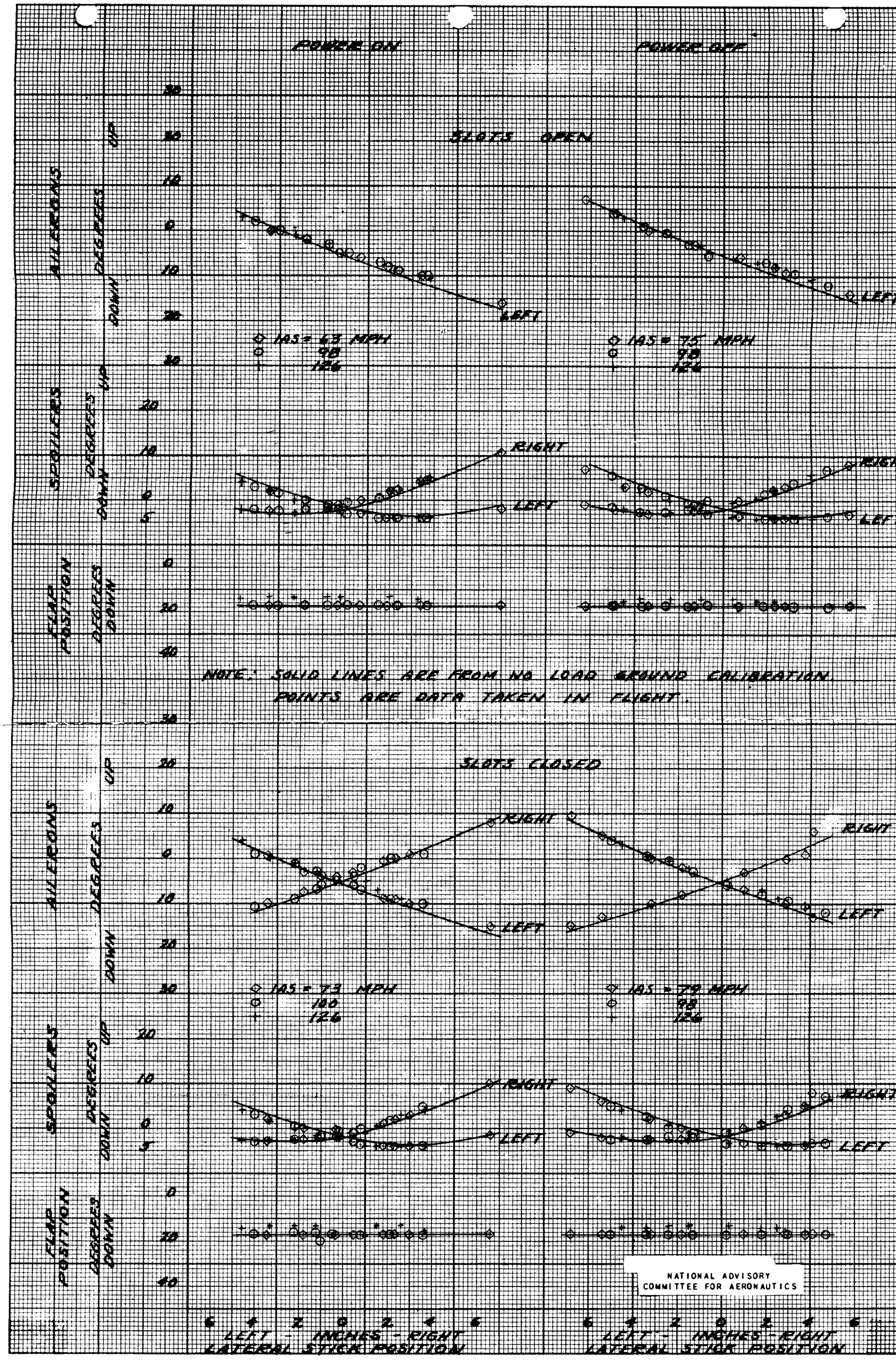


Figure 50.- Stretch in the lateral control system as measured in steady sideslipping flight. Test airplane with flaps set 1/3 down.

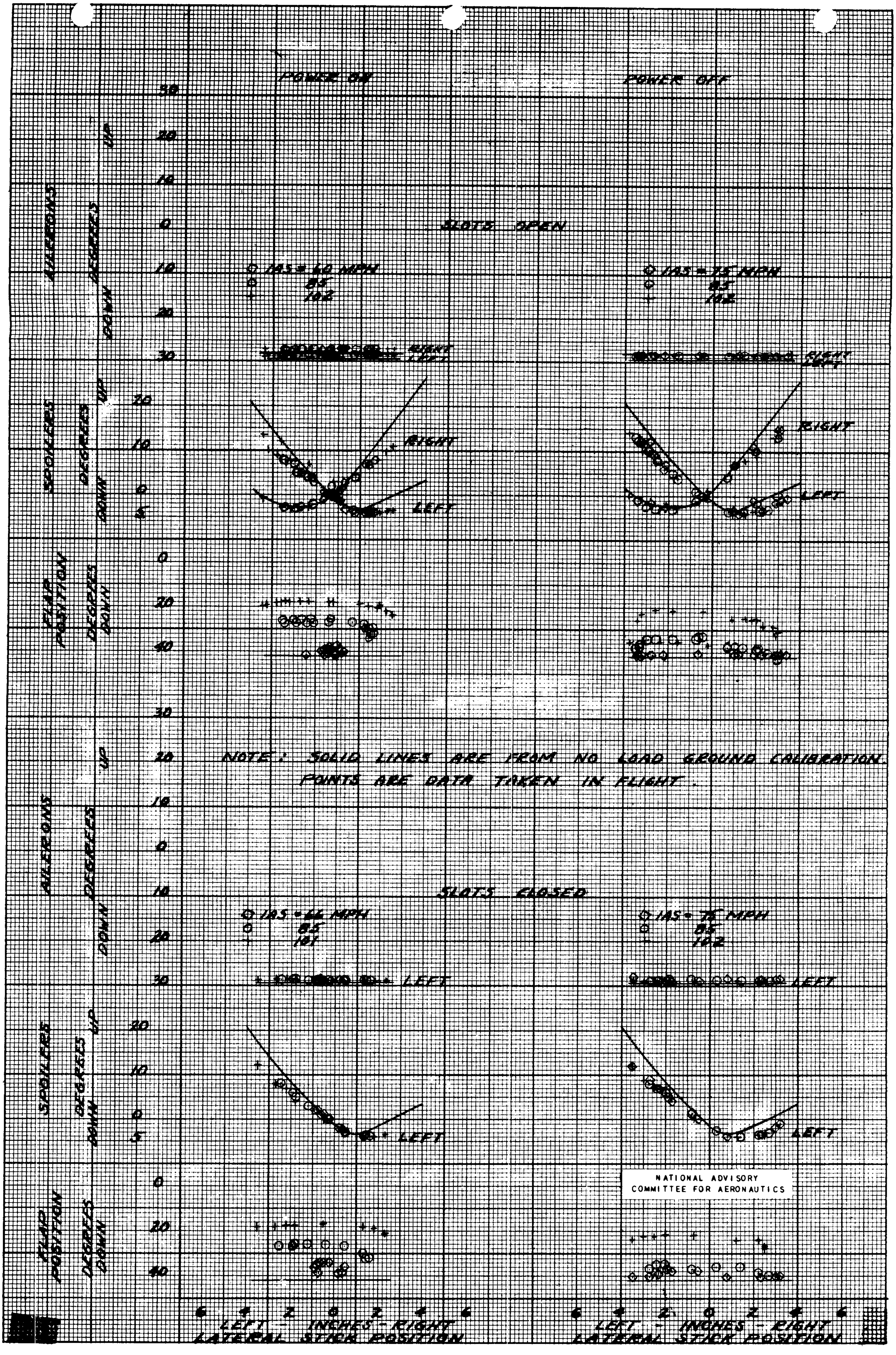


Figure 51.- Stretch in the lateral control system as measured in steady sideslipping flight. Test airplane with flaps set full down.

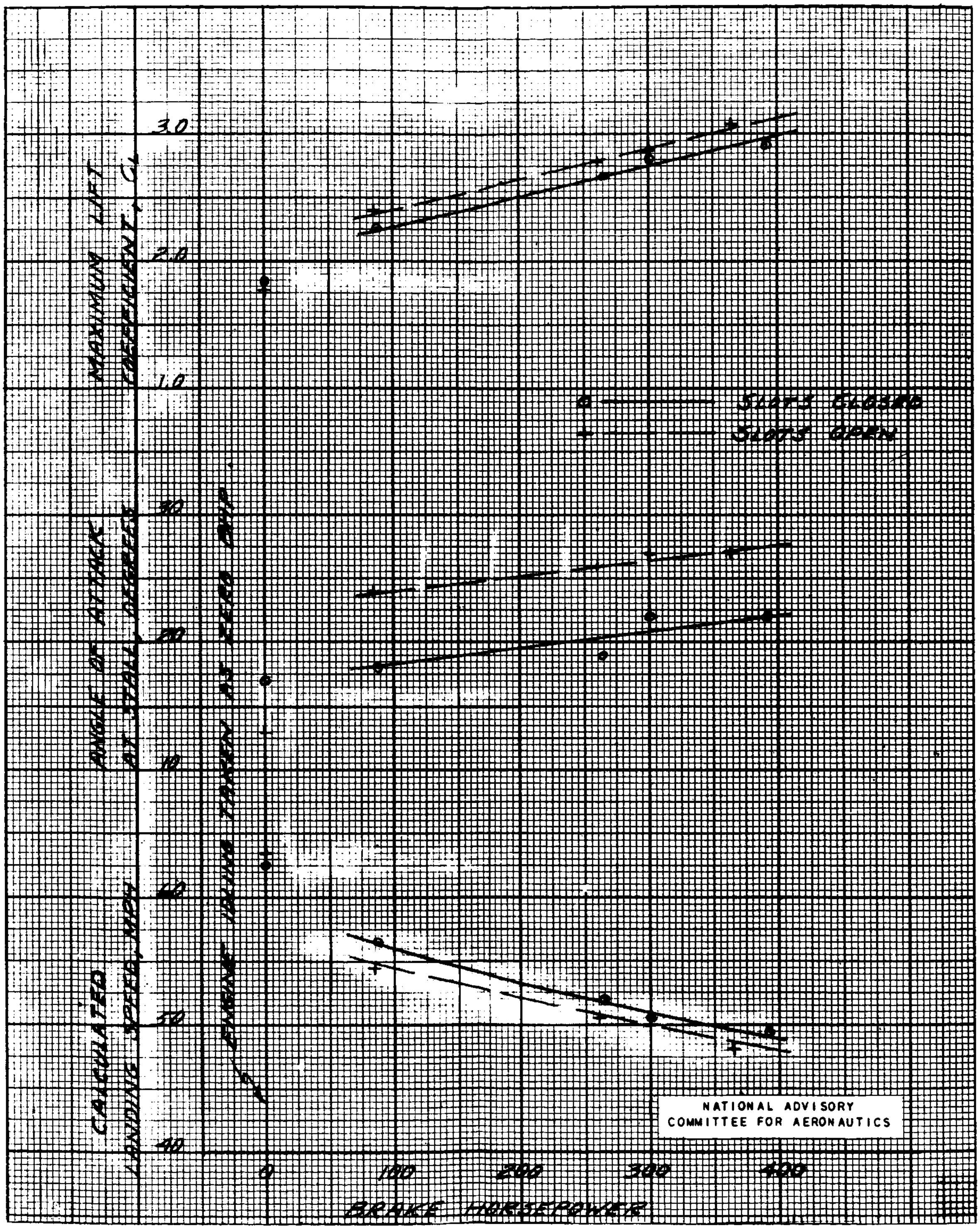


Figure 52.- Variation of maximum lift coefficient with power. Flaps full down, hoods open, cowl flaps open, center of gravity at 32.1 percent M.A.C.

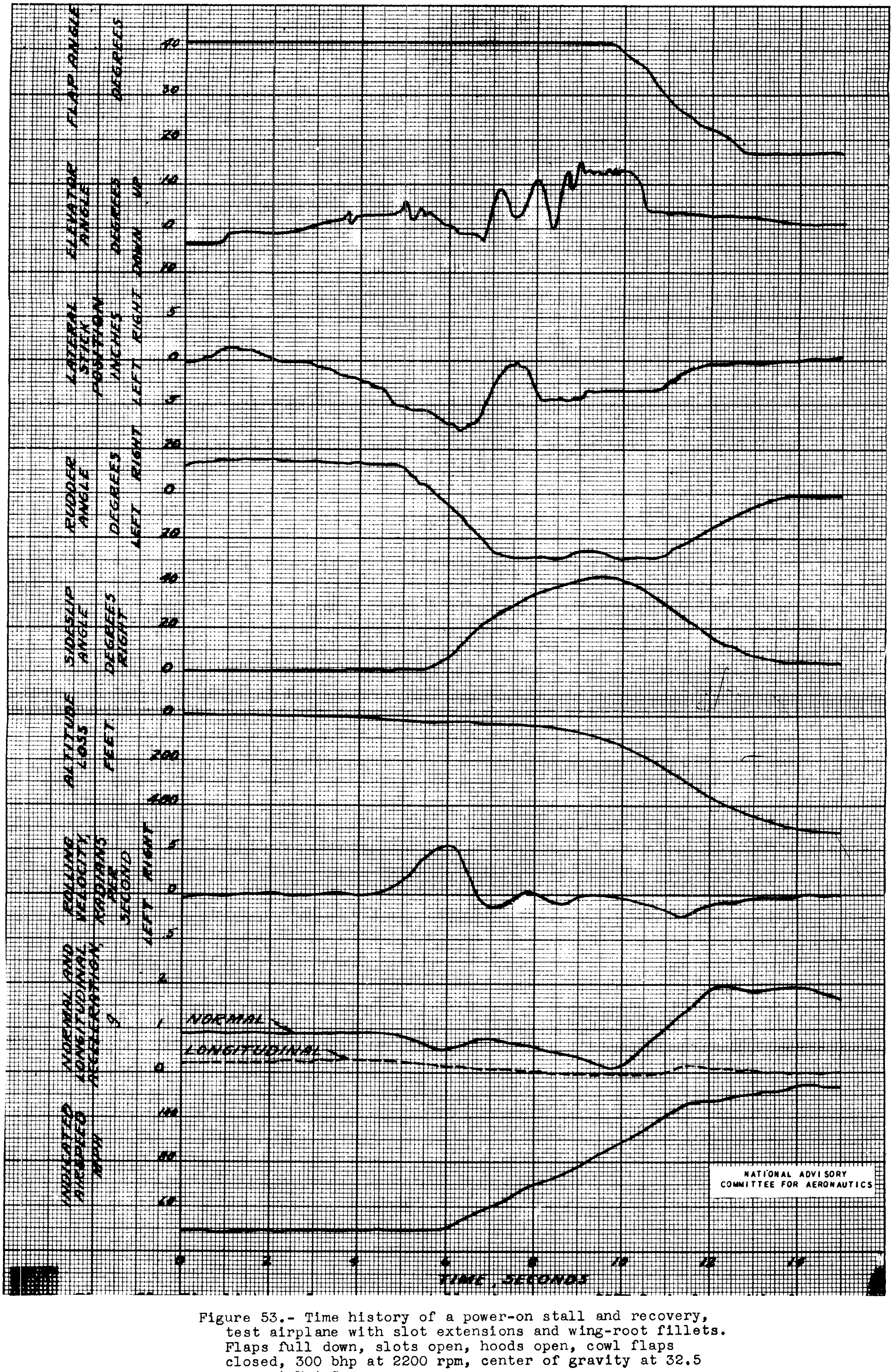


Figure 53.- Time history of a power-on stall and recovery, test airplane with slot extensions and wing-root fillets. Flaps full down, slots open, hoods open, cowl flaps closed, 300 bhp at 2200 rpm, center of gravity at 32.5 percent M.A.C.

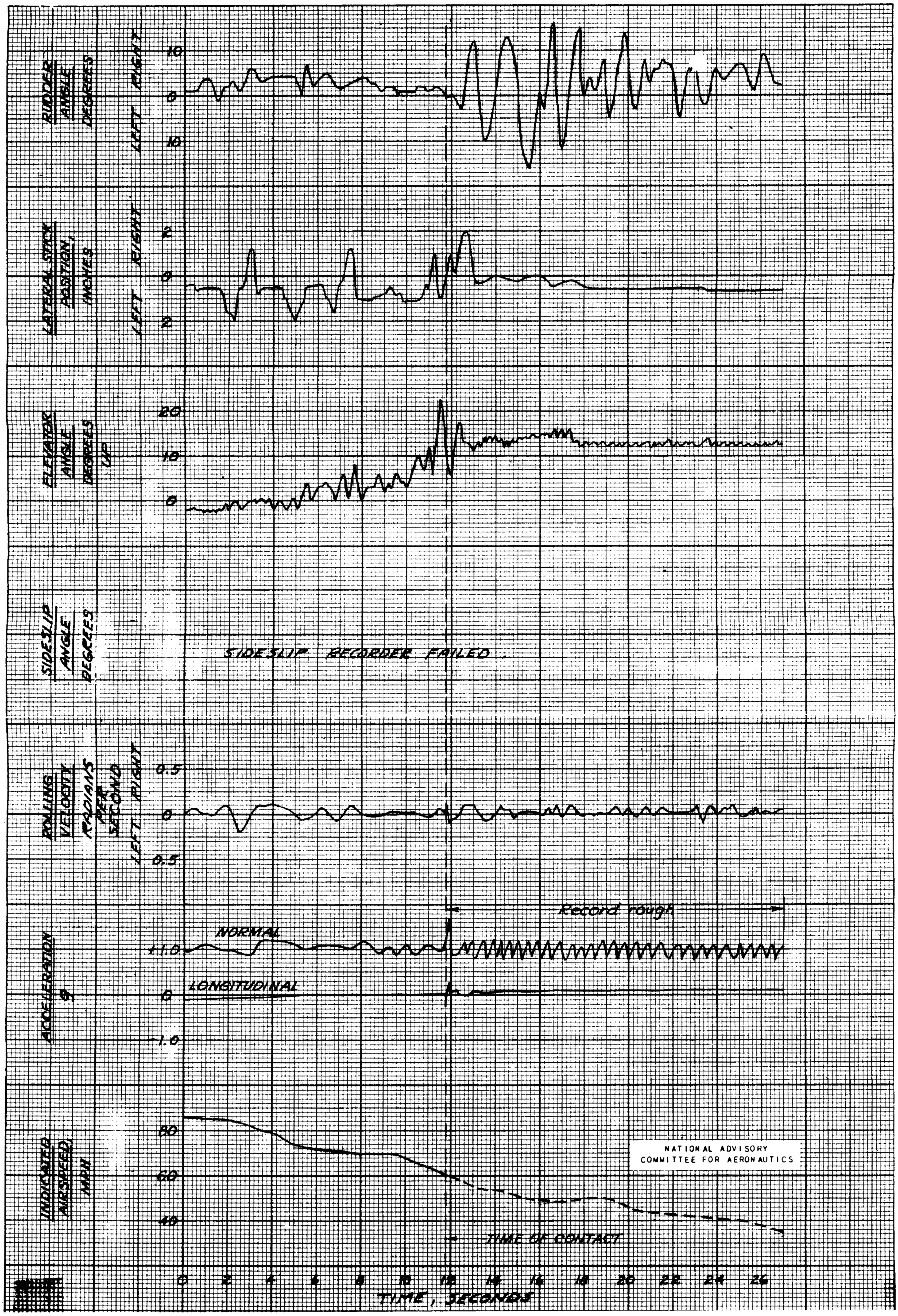


Figure 54.- Time history of a three-point, power-off landing, with flaps full down, slots, hoods, and cowl flaps open. Test airplane with Maxwell slot extensions and smooth walkway.

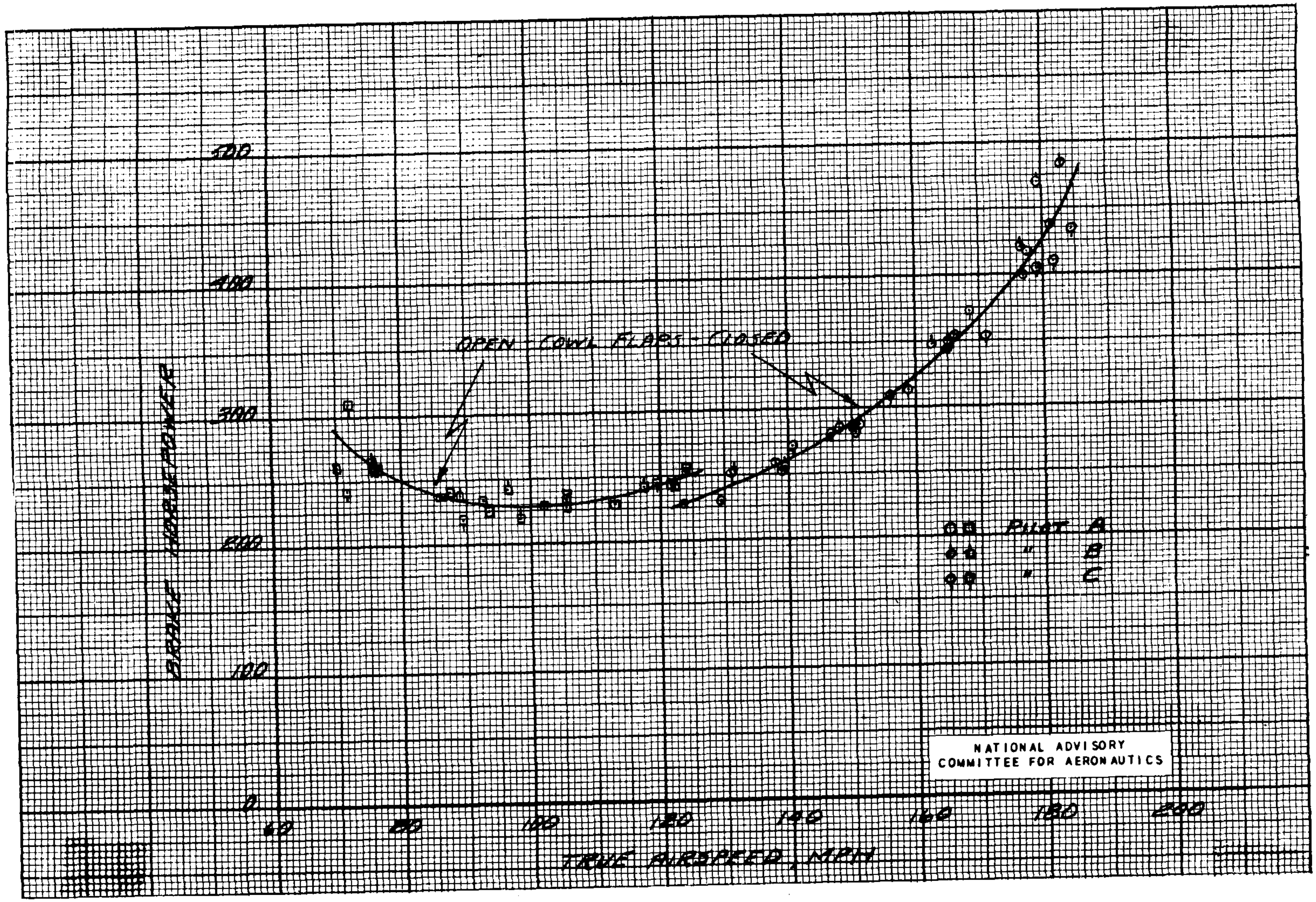


Figure 55.- Power required for level flight at 5500 feet density altitude and 4800 pounds weight. Test airplane with flaps up, slots closed, hoods closed.

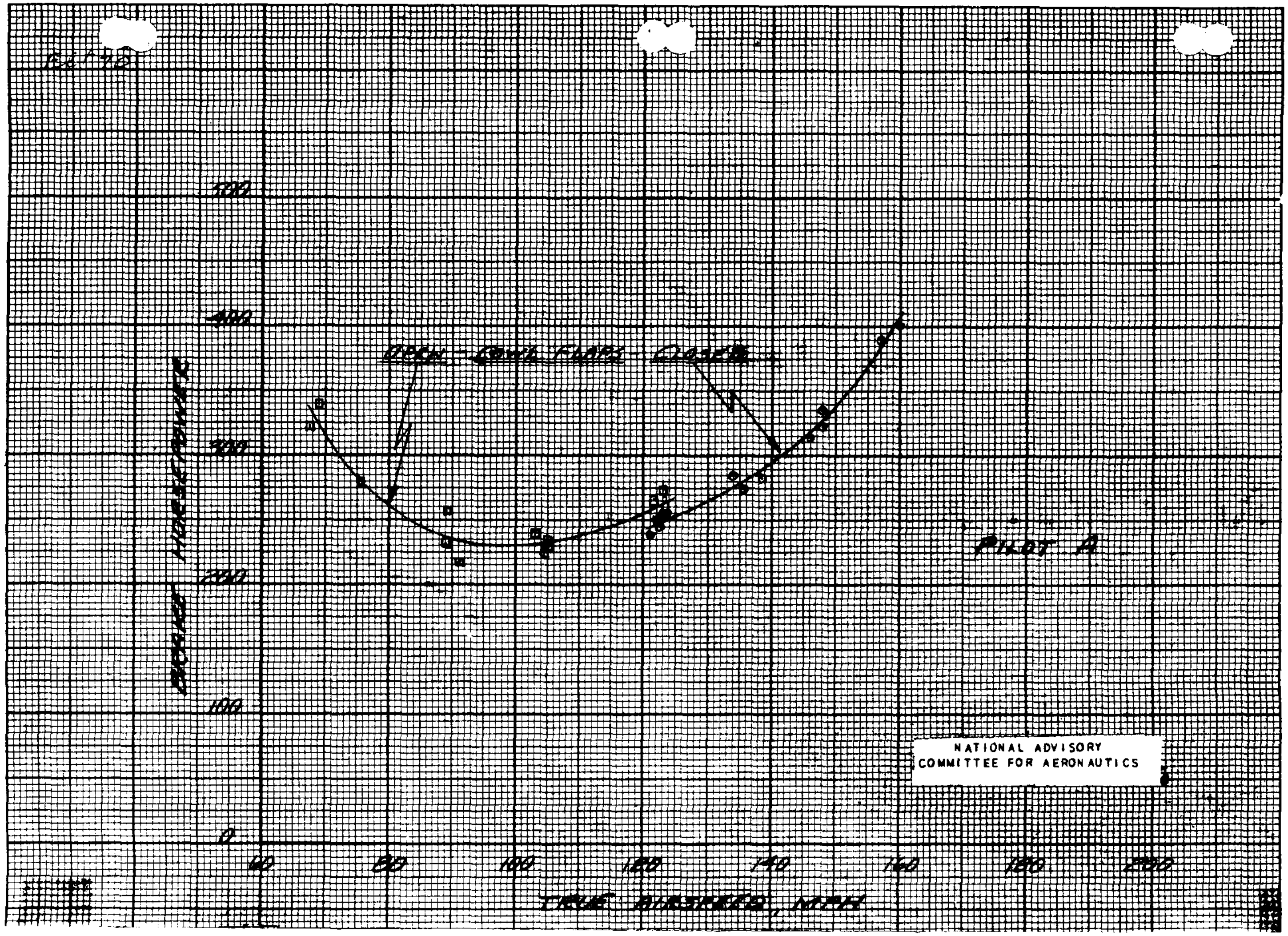


Figure 56.- Power required for level flight at 5500 feet density altitude and 4800 pounds weight. Test airplane with flaps up, slots open, hoods closed.

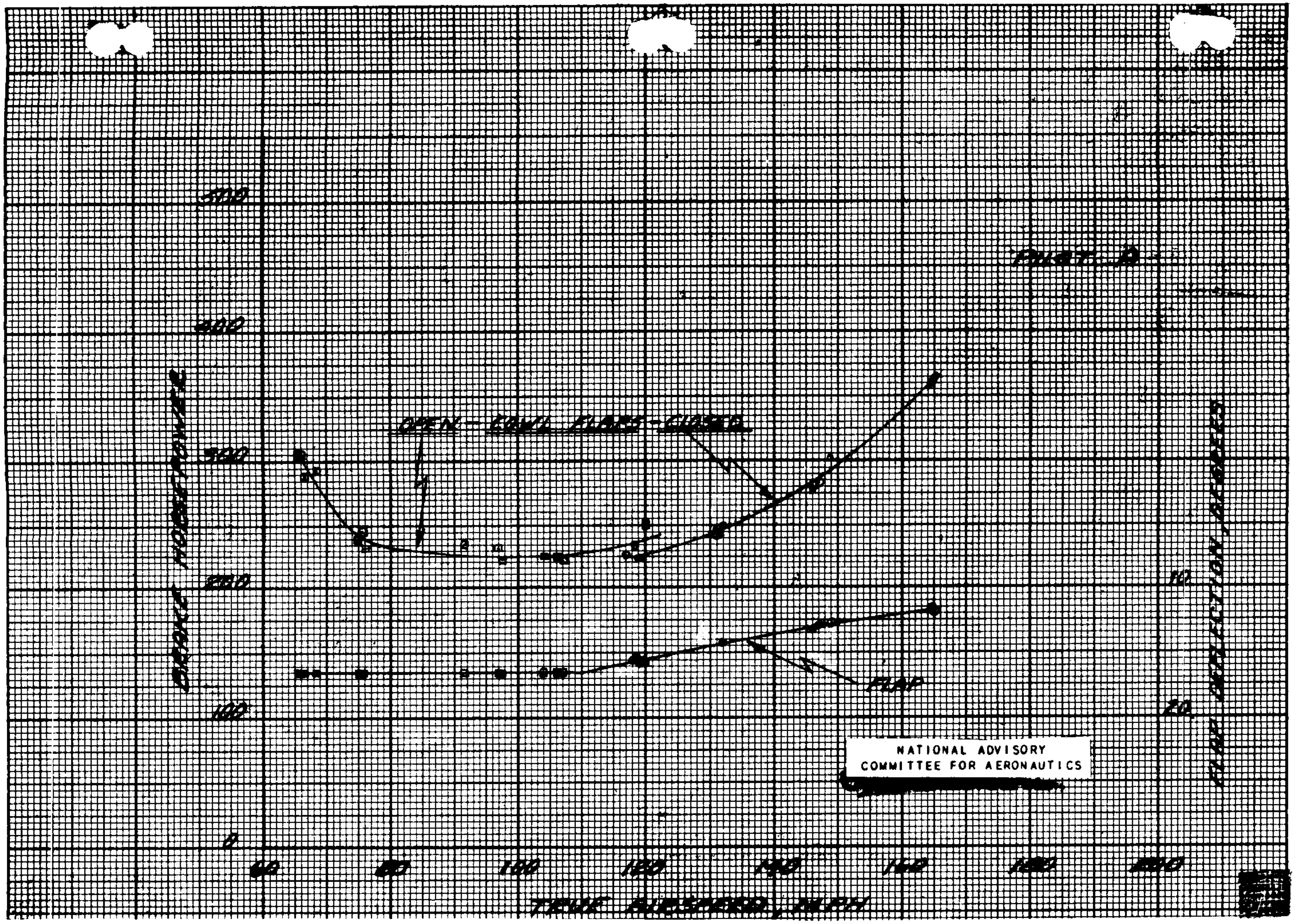


Figure 57.- Power required for level flight at 5500 feet density altitude and 4800 pounds weight. Test airplane with flaps set for 16.5° deflection, slots closed, hoods closed.

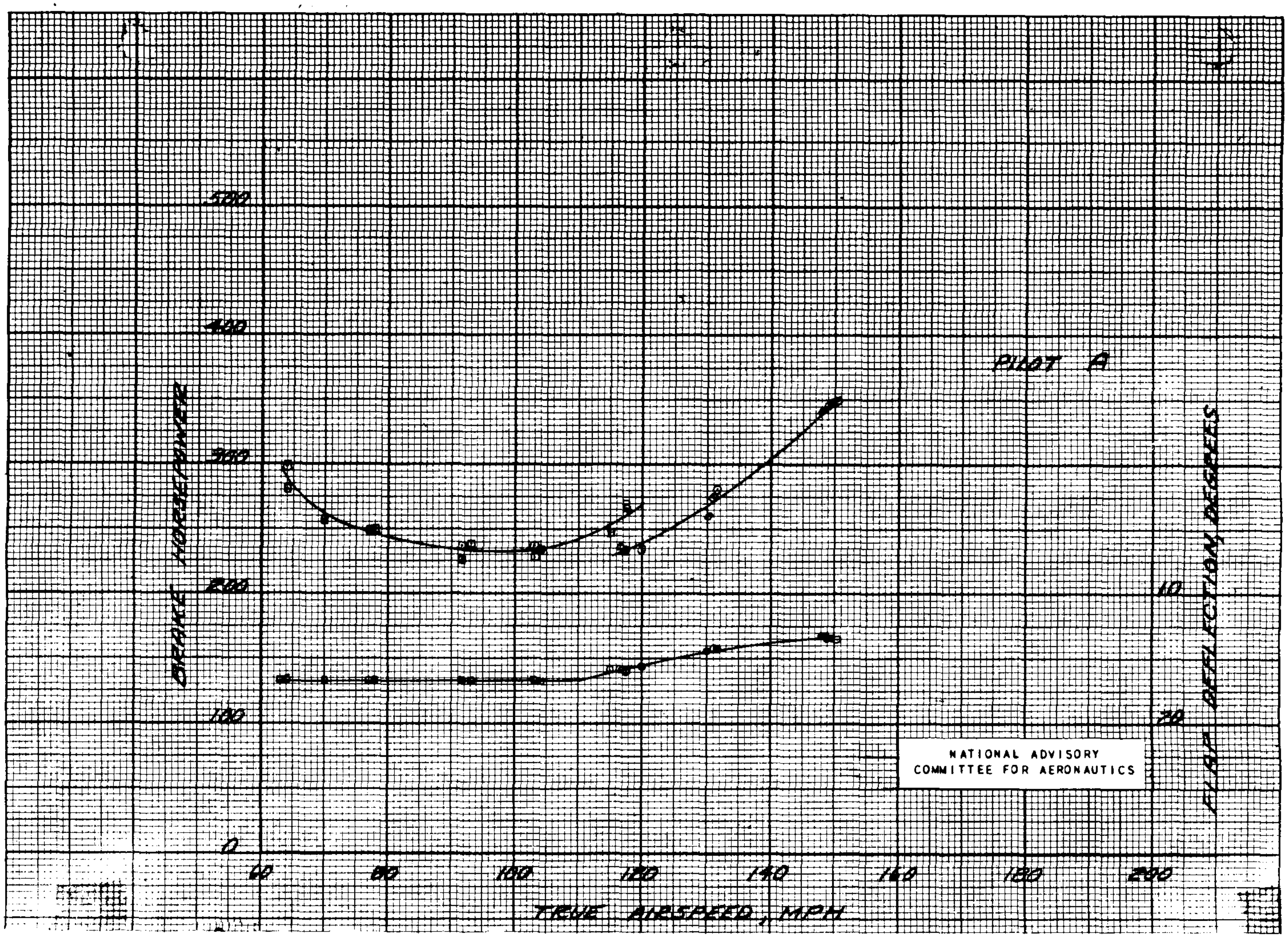


Figure 58.- Power required for level flight at 5500 feet density altitude and 4800 pounds weight. Test airplane with flap set for 16.7° deflection, slots open, hoods closed.